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**Journal
of the
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Vol. 44

Part 1

1.—The "Greenstones" of South Western Australia

Presidential Address, 1960

By Rex T. Prider, B.Sc., Ph.D., M.Aust.I.M.M., F.G.S.*

Delivered—18th July, 1960

In preparing my Address for this evening I first looked back at some of the Addresses given by former Presidents of this Society whose interests were in the same field as mine—that is the field of "hard rock geology"—and I find that, naturally enough, since Western Australia forms the solid Precambrian nucleus of Australia, they all chose to speak about the Precambrian of Western Australia. My predecessor and colleague in the Geology Department at the University, the late Professor Clarke, in 1923 spoke about "The Precambrian succession in some parts of Western Australia," the late Mr. Gibb Maitland in 1927 dealt with "The volcanic history of Western Australia," and Mr. Frank Forman addressed us in 1937 on "Further contributions to our knowledge of the Precambrian of Western Australia." In 1945 when I served a previous term as President my address dealt with "Igneous activity, metamorphism and ore formation in Western Australia" which really amounts to a consideration of the Precambrian. Finally, my colleague Dr. Allan Wilson, now Professor of Geology in the University of Queensland, in 1958 gave as his address "Advances in the knowledge of the structure and petrology of the Precambrian rocks of south-western Australia" in which he reviewed the advances made in our knowledge of the Precambrian shield since the publication of my 1945 address. I am afraid that we are not working sufficiently fast for me to be able to offer a further contribution with this title so I propose to deal with one of the important groups of rocks occurring in our Precambrian—the so-called "greenstones."

One of the most striking features of the geological map of Western Australia published by the Geological Survey of Western Australia in 1957 is that the greater part of the southern half of the State is made up of Precambrian granitic rocks within which there are many north-north-westerly trending belts shown in green which are labelled "Archaeozoic Greenstone Phase." Looking more closely at this map we notice that all of the main gold mining fields are confined to these "Greenstone" belts. Indeed, the Mines

Department in 1945 published a mineral map showing the "gold" areas of Western Australia (Fig. 1). These "gold arcs," as will be seen on comparing these two maps, are the greenstone belts, for it has been long realised that, from the mining point of view, this is the country where prospecting for gold is most likely to be successful. Indeed, with the exception of the auriferous conglomerates of Nullagine in the vicinity of Marble Bar, no auriferous ore deposit of any significance has been found outside these belts. Little wonder, therefore, that to the mining man in Western Australia "greenstone" has become the most important of the rocks making up this country, and the word "greenstone," used both in the lithological and stratigraphical sense, has become at once the most used and most ill-used of the terms in Western Australian mining and geological publications.

Throughout Western Australian geological literature we continually find reference to fine-grained greenstones, coarse-grained greenstones, massive greenstones, schistose greenstones, greenstone lava schists, altered greenstones, unaltered greenstones, phyllitic greenstones, clastic greenstones, and so on. The use of such names without further petrological data leaves the reader with very little real information about the rock.

The term "greenstone" has also been used in a stratigraphic sense, though not always in conformity with present day usage of stratigraphic nomenclature. Thus, at Kalgoorlie where the Precambrian geology has been the subject of close study since gold was discovered there in 1892 we find that the "Greenstone Phase" of the Archean Kalgoorlie-Yilgarn System consists of the "Older Greenstone Series" and the "Younger Greenstone Series." Indeed, throughout the shield these two distinct episodes of basic igneous activity can be recognised and the rocks have become generally known as the Older Greenstones and Younger Greenstones.

The chaotic state of petrological nomenclature of these greenstones is again evident from the published works dealing with the geology of Kalgoorlie. One of the representatives of the Younger Greenstones has been described at vari-

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ous times by various geologists as "quartz dolerite amphibolite" (Thompson 1913), "epidiorite" (Feldtmann 1916), "uralitic quartz dolerite" (Stillwell 1928), "quartz dolerite" (Campbell 1953), "unaltered greenstone" (mining geologists in conversation). One cannot wonder at the mining geologist referring to this rock incorrectly as "unaltered greenstone" when so many different names have been given to it as I have indicated.

Many may say "Well, what does it matter?" I feel that it does matter since some of the "greenstones" are favourable host rocks for the auriferous deposits, whereas others are unfavourable. Again, structural mapping is dependent on ability to recognise and distinguish the different greenstones. Moreover, if one understands the origin of the rock he is dealing with he can get a great deal more information from it concerning structure, which is of prime importance in economic geology, than he would otherwise obtain.

I have been prompted, therefore, to look a little more closely at these greenstones in the hope that some order can be put into the present chaos so far as these important rocks are concerned.

Nomenclature

The name Grünstein appears to have been first used in 1787 by Abraham Gottlob Werner of the Freiberg Mining Academy in Saxony as a group name for greenish altered basic igneous rocks.

Greenstone, according to Holmes (1928), is "an old field term applied to more or less altered basaltic or doleritic rocks, the characteristic dark green colour being due to the presence of chlorite, hornblende, epidote, etc. as in diabase and epidiorite." This is the sense in which the term has generally been used. (e.g. Robson 1953), but there are other local usages of the term "greenstone." In New Zealand, for example, it is used as a group name for the fine-grained rocks consisting essentially of either tremolitic amphibole or serpentine, which were used by the Maoris in the manufacture of implements and ornaments (Turner 1935; Reed 1957).

If now we add to these altered igneous rocks the "green beds" of sedimentary origin, together with the products of various kinds and grades of metamorphism on all of these rocks we have the rocks of very varied origin and age, which hitherto in Western Australia, have been referred to as "greenstones." These rocks have, in many cases, been further named meta-dolerites, coarse-grained greenstone, epidioritic dolerite, and so on, as I have already indicated. In many instances they have been incorrectly named—by and large all names of greenstones published by the Geological Survey of Western Australia during the past twenty years are field names and have not been determined after examination with the microscope. In effect, because of lack of petrographic data, the reader is not in a position to determine what these rocks are, other than they are green. So we are still confronted with a greenstone problem which nearly 100 years ago worried the geologist Forbes (1867, p. 57) who said "incorrect views have been

formed by persons not much acquainted with petrology and mineralogy from their confounding certain rocks with names which did not, in reality, pertain to them. An example, illustrative of this, may be cited: The writer of these remarks, finding from an examination of the sheets of the Geological Survey that large masses of greenstone were represented as occurring in Cornwall, near Penzance, and at the Botallack mines, immediately imagined that he would there find the same relations of the greenstone to the metallic lodes, occurring as he had found to be the case in South and North America, Spain, Norway, Sweden, etc., and made a journey expressly for this examination; on arrival he at once found that the rocks had evidently been metamorphosed *in situ*, and they no doubt originally had only been the ordinary sedimentary clay-slates. Had he now been content with the decision of the Geological Survey that the rocks in question really were greenstones, then he must at once have come to the conclusion that greenstones could be formed by the alteration of clay-slates *in situ*. It did not, however, require a long examination to prove that the rocks were neither petrologically, mineralogically, or chemically, greenstones, or even any allied rock, being nothing more than clay slates altered *in situ* and possessing none of the properties of greenstones beyond the greenish tinge which coloured them."

Let us look for a moment at the way in which the rocks, which in Western Australia have been referred to as "greenstones" have developed, their characteristics, and their nomenclature. They may be derived from igneous or sedimentary parent materials. Igneous rocks are those which have crystallised from magma and broadly speaking we find the two contrasted types:

- (i) The acid rocks which have high silica, alumina, and alkali content and correspondingly low lime, magnesia and iron. These are light-coloured rocks made up largely of minerals such as quartz and felspar with minor amounts of the dark-coloured iron- and magnesium-bearing minerals.
- (ii) The basic rocks which have lower silica and alkalies and correspondingly higher iron and magnesia content. They are dark in colour and made up largely of the various ferromagnesian minerals which appear to be black or green in hand specimen.

In both of these contrasted groups we find rocks of varying grain size—where they have cooled quickly, as when extruded from volcanic vents on to the Earth's surface they are fine-grained. Where they have cooled slowly at depth and crystals have had more time to form the grain is coarser-textured. Now we have every gradation between acid and basic rocks according to the chemical composition of the parent magma and the extent to which it has been differentiated, and every gradation in grain size from fine to coarse according to the rate at which cooling has taken place. It is from the rocks of basic to intermediate chemical character that most of our greenstones of igneous origin

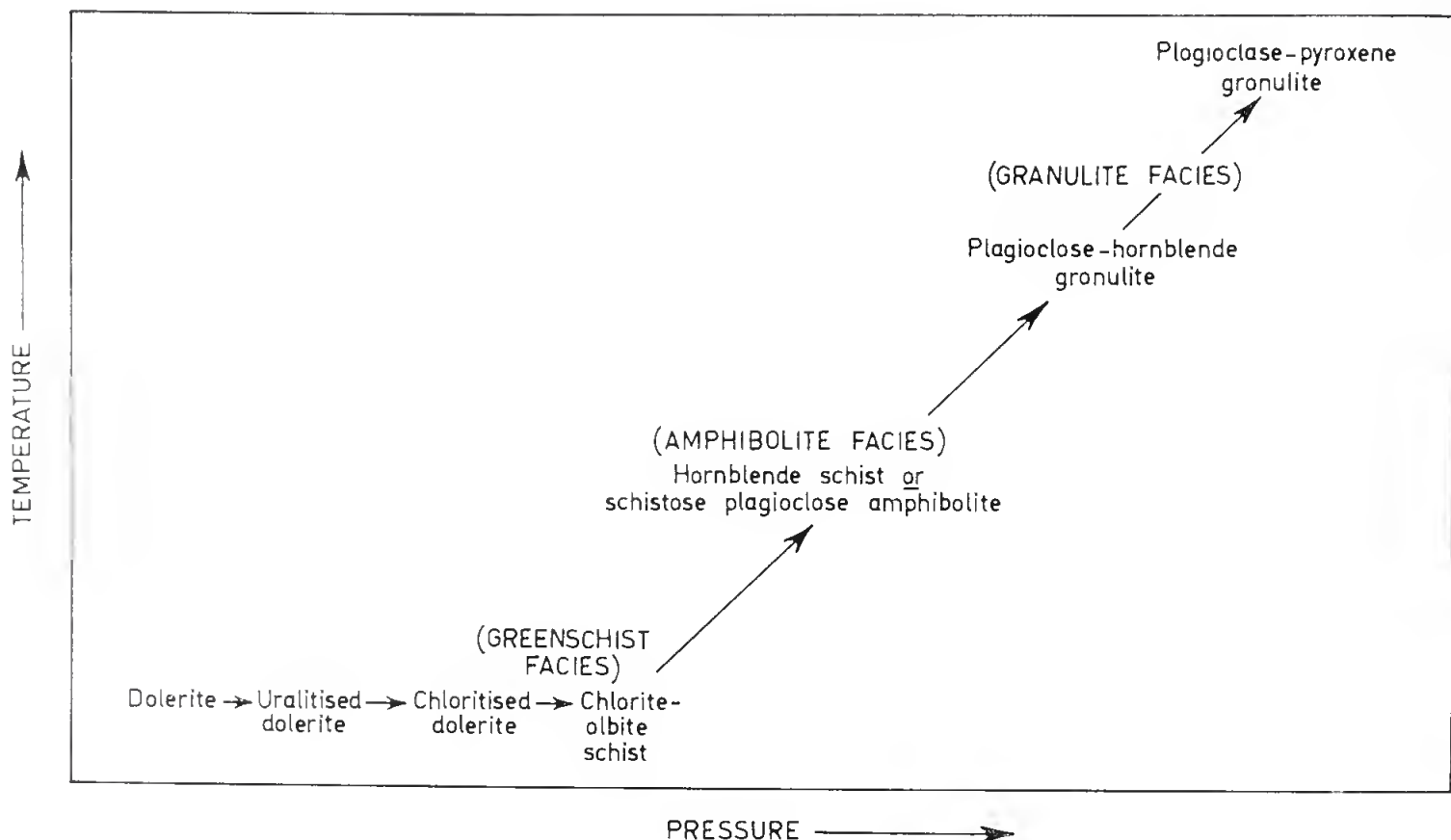


Fig. 2.—Relationship of the metamorphic derivatives of dolerite.

have developed, and the general features of these rocks may be seen by the examination of the effects of different grades of metamorphism on a parent basic igneous rock such as dolerite. Dolerite consists essentially of plagioclase and clinopyroxene. On slight shearing, or under the influence of end-stage liquids during the final phases of consolidation, the pyroxene is converted in varying degree into fibrous green amphibole (uralite) yielding rocks such as slightly to completely uralitised dolerite. In such rocks the original ophitic texture and grain are retained and the original black dolerite is changed to a greenish rock best described as uralitised dolerite. Under higher directed stress the fibrous uralite is converted to chlorite to yield chloritised dolerites. The original textures are still retained at this stage but with further recrystallisation under higher temperature conditions the original textures become obscured and we have the development of the schistose rocks such as the chlorite-albite schists of the greenschist facies. Under conditions of increasing temperature further recrystallisation yields, in turn, the schistose plagioclase amphibolites (hornblende schists) of the amphibolite facies and finally, under high temperature-high static pressure conditions, the plagioclase-pyroxene granulites (such as the basic charnockites) of the granulite facies as indicated in Fig. 2.

Basalts (fine-grained), dolerites (medium-grained) and gabbros (coarse-grained) are all of similar chemical composition and contain similar mineral assemblages and will yield products similar to those already mentioned. So we will find uralitised basalts, chloritised basalts, amphibolites and granulites. In the lower grade metamorphic derivatives (the uralitised and

chloritised rocks) the original microstructures and textures may be preserved and the nature of the parent rocks, whether extrusive or intrusive, may be determinable. Once recrystallisation to produce the various amphibolites and granulites takes place these original features tend to disappear and only the larger structures such as pillows and amygdulæ remain and in the highest grades of metamorphism even these will disappear.

In volcanic areas earlier-extruded lavas such as basalts may be fragmented by later explosive activity yielding a group of clastic rocks (the pyroclastics) which are of similar chemical composition to the parent materials and these, on metamorphism, will result in similar rocks to those I have just mentioned.

Again, the breakdown of these rocks by weathering will yield fragmental products. If this process is slow, chemical weathering will be dominant and the result will be iron-stained clays. If, on the other hand, the breakdown has taken place comparatively quickly, as on a land surface of considerable topographic relief, the resultant sedimentary rocks will be of greywacke type—made up of small rock fragments of the pre-existing rocks in a clayey groundmass. Metamorphism of these clastic materials will produce chloritised greywackes (in which relict clastic textures can still be observed), chlorite schists, and various amphibolites such as hornblende-plagioclase schists and hornblende-plagioclase granulites. The higher the grade of metamorphism, the more the original textures, which indicate the nature of the parent rock, will be obscured, so that it may be very difficult to determine whether the final product was originally igneous or sedimentary in origin.

Another group of "greenstones" is that derived from the ultrabasic igneous rocks. Rocks which originally consisted entirely of olivine or pyroxene, have been converted during metamorphism to a variety of serpentinites, talc-chlorite rocks, and amphibolites. Here again, many of the ultrabasic "greenstones" may well prove to be derived from sedimentary parent materials such as cherty dolomitic limestones.

The Archean Greenstones of South Western Australia

The oldest recognisable rocks in the Western Australian Shield are the rocks of volcanic origin, the so-called Older Greenstone Series, which form the bulk of the greenstone areas of the various goldfields. That these rocks are largely of volcanic origin is evidenced by the presence in them of relicts of the original agglomeratic, amygdaloidal and pillow structures. These are structures which we know from our observations of present day igneous activity are the result of explosive volcanism and extrusion of molten rock material on to the Earth's surface. Of these structures the pillow structure is of particular significance since it indicates the nature of the early Precambrian volcanism and is one of the keys to the present geological



Fig. 4.—Pillow structure in highly weathered steeply dipping Older Greenstones exposed on horizontal surface on west flank of Mt. Hunt, south of Boulder in the Kalgoorlie Goldfield. Top of sequence to the right. (Photograph: R. T. Prider).

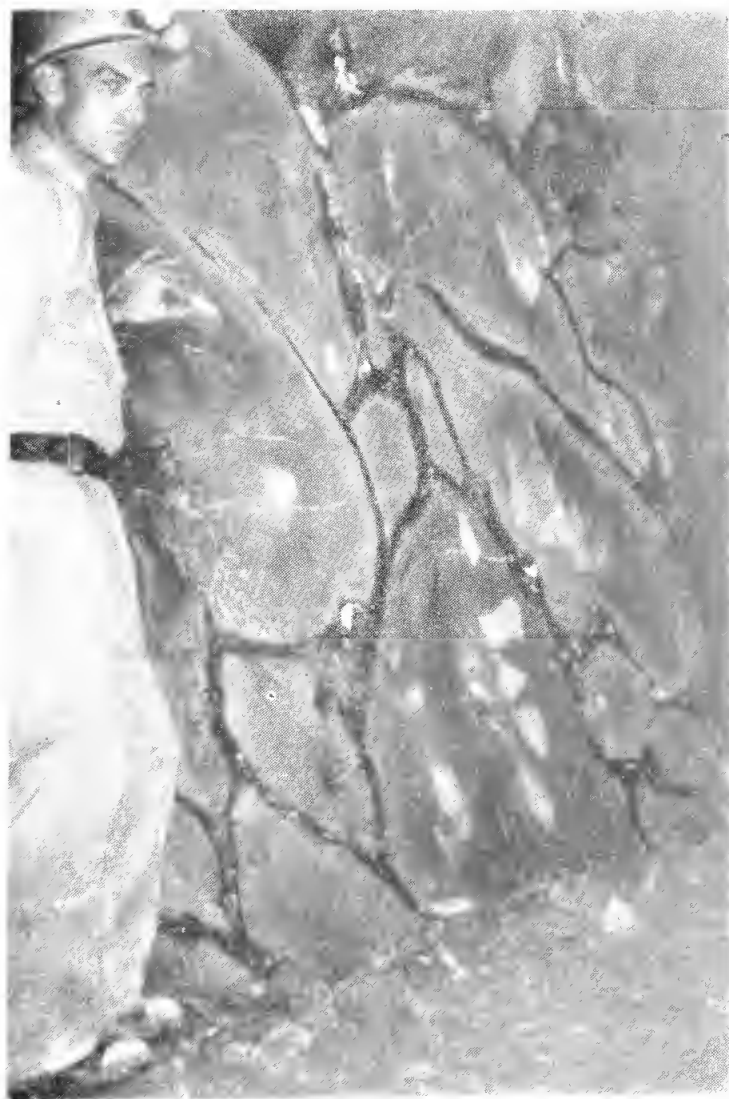


Fig. 3.—Pillow structure in carbonated Older Greenstones, No. 5 level, Brownhill Mine, Kalgoorlie. View looking south showing west-facing flow dipping approximately 60° west. (Photograph: G. Scott).

structure. When molten lava flows into standing water such as a swamp, a lake or the sea, it breaks up into bulbous masses, spheroidal or ellipsoidal in shape, which settle down on top of one another. These masses being still somewhat plastic take on the shape of the surface onto which they are deposited and the form of the pillows thus provides evidence of top and bottom of the sequence. This pillow structure has been noted in the early Archean volcanics in many localities in Western Australia. The best known occurrences which are at Kalgoorlie (Fig. 3), Norseman and Wiluna recall the pillow structure so characteristic of the Kewatin lavas of the Canadian Shield. These structures may be retained even in completely recrystallised rocks, such as the hornblende schists of Palmer's Find near Yellowdine in the Yilgarn Goldfield, and also in completely weathered rocks as at the Transcontinental Railway Line cutting at Kalgoorlie and Mt. Hunt, south of Boulder (Fig. 4). In the Mt. Hunt example figured the rocks have been converted by weathering into a soft friable reddish clay—nevertheless it is still possible to say which is top and bottom of the original flow.

The most closely studied area of Archean greenstones is that of the East Coolgardie Goldfield, particularly in the vicinity of Kalgoorlie, and we might well take Kalgoorlie as the type area for the Archean greenstones. Here we find that there are two distinct ages of Archean greenstones:—

- (i) The *Older Greenstones* which were basaltic lavas, in places containing pillow structure indicating that they were perhaps submarine extrusions; an hypothesis which is supported by their soda-rich spilitic character and by the presence locally of interbedded banded ferruginous cherts (jaspers).

- (ii) The *Younger Greenstones* which were quartz dolerite and related rocks occurring as concordant (sill or laccolith) intrusions into the *Older Greenstones* and overlying *Black Flag* sediments.

The *Kalgoorlie Greenstones* have been subjected to very intense shearing and the metasomatic activity of CO_2 and siliceous liquids and vapours so that the rocks are now very different from the original basalts and dolerites. Unless one has had extensive experience with these highly metasomatised rocks the microscope is not of very great value for distinguishing the different types of greenstone. In fact, the regional shearing and metasomatism that has affected the *Kalgoorlie greenstones* tends to reduce them all to a common end-product—a felted aggregate of chlorite, epidote, albite and various carbonate minerals (probably mainly ankerite). If we would determine the original nature of these rocks then we must abandon mineralogical and chemical composition as criteria and rely entirely on relict textures and structures. Some of these—such as the occurrence in the *Younger Greenstones* of end-stage quartz with apatite needles, relict ophitic texture and leucoxenised ilmenite plates—can be seen with the microscope, but by and large the relict textures in these highly metasomatised rocks are best examined with low magnification on polished surfaces (Fig. 5). No matter how highly carbonated or pyritised these rocks are,



Fig. 5.—Lodestuff (highly sheared, carbonated, pyritised, chloritised quartz dolerite) showing relict textures which are best examined under low magnification on polished surfaces. Central strip of photograph in which the texture is visible is a polished surface of specimen. ($\times \frac{1}{2}$). (Photograph: K. Bauer).

the original basaltic or coarser doleritic character can be determined in this way—the dolerite derivatives of the *Younger Greenstones* for example can always be distinguished from the finer grained basalts of the *Older Greenstones* by the grey skeletal-structured leucoxenised ilmenites.

The *Archean Greenstones* of *Kalgoorlie* may be classified as set out in Table I.

The *Older Greenstones* consist of a sequence of volcanic flows and interbedded pyroclastics. Spilitic flows with pillow structure are characteristic. When naming the rocks the term "basalt" should be further qualified as massive, amygdaloidal, variolitic or pillow-structured according to the structure. There are no unaltered basalts in the *Kalgoorlie District*. They have all been altered to some extent, culminating in intense carbonation, silicification and pyritisation along shear zones to yield the auriferous lodes.

The intrusive *Younger Greenstone* magma appears to have been differentiated to yield:—

- (i) *Ultrabasics* such as pyroxenites and peridotites now represented by uralitised pyroxenite ("hornblendite"), serpentinites, talc-chlorite-carbonate and fuchsite-quartz-carbonate rocks.
- (ii) *Basic rocks* such as dolerite and quartz dolerite and their coarser gabbroic equivalents. Again there are very few of these rocks which carry any relict pyroxene.
- (iii) *Porphyries* represented by chloritised hornblende porphyrites and albite porphyries. Some of the so-called albite porphyries or "bedded porphyries" are actually sedimentary rather than igneous rocks and have resulted from the soda metasomatism of claystones by the intrusive basic *Younger Greenstone* magma to yield adinoles. The intrusive albite porphyry dykes are considered by most authors to be related to a hypothetical granite magma at depth, but I have included them here because of the possibility (Prider 1940) of them being genetically related to the *Younger Greenstone* magma.

As far as the ultrabasics are concerned, there can be little doubt that the uralitised pyroxenites belong with the *Younger Greenstones*. The serpentinites, however, may belong to the *Older Greenstones*. The oldest *Precambrian* rocks of the *Canadian Shield* (the *Keewatin*) and of *Southern Rhodesia* (the *Sebakwian*) are basic (often pillow) lavas and serpentinitised peridotites like those at *Kalgoorlie*. Moreover, this association is ubiquitous throughout the *Canadian*, *African* and *Australian Shields*. Hess (1955, p. 399) has pointed to the probable similarity of such widespread basic lava-serpentine associations to the present earth crust beneath the oceans, and it may well be that in these rocks we see an exposure of the primordial earth crust.

These associations of fine-grained greenstones, coarse-grained greenstones and ultrabasics have been recognised in most of the greenstone areas of the *Western Australian goldfields*. While the *Older Greenstones* have generally been regarded

TABLE I.

Classification of the greenstones of Kalgoorlie
(Earlier commonly used names are shown in parentheses)

Increasing shear and metasomatism →

| | Original rocks | Uralitic stage | Chloritic stage | Carbonated stage | Silicified and pyritised stage |
|---------------------|---|--|--|--|------------------------------------|
| OLDER GREENSTONES | Basalt—massive, amygdaloidal, variolitic or pillow-structured | Uralitised basalt (Fine-grained amphibolite) | Chloritised basalt (Fine-grained greenstone) | Carbonated chloritised basalt and Carbonate-chlorite schist (Bleached fine-grained greenstone and Calc schist) | Lodestuff (do.) |
| | Agglomerate | Uralitised agglomerate (Fine-grained amphibolite) | Chloritised agglomerate (Fine-grained greenstone) | Carbonated chloritised agglomerate and Carbonate-chlorite schist (Bleached fine-grained greenstone and Calc schist) | Lodestuff (do.) |
| | Albite porphyry | Sericitised albite porphyry (Albite porphyry, Albite porphyrite, Keratophyre) | | Carbonated albite porphyry | Lodestuff—generally very low grade |
| YOUNGER GREENSTONES | Claystone | Adiuole (Albite porphyry) | | Carbonated adiuole | |
| | Hornblende porphyrite | | Chloritised hornblende porphyrite | | |
| | Quartz dolerite | Uralitised quartz dolerite (Quartz dolerite amphibolite, Epidiorite, Actinolite-zoisite amphibolite, Uralitic quartz dolerite, Quartz dolerite, Unaltered greenstone) | Chloritised quartz dolerite (Quartz dolerite greenstone, Coarse-grained greenstone, Altered greenstone) | Carbonated chloritised quartz dolerite (Bleached quartz dolerite greenstone) | Lodestuff (do.) |
| | Pyroxenite | Uralitised pyroxenite (Hornblendite) | | | |
| | Peridotite | Serpentine | Talc-chlorite rock (Talc-chlorite rock) | Talc-chlorite-carbonate rock (Talc-chlorite-mesitite rock) | Fuchsite-quartz-carbonate rock |

as altered volcanics, in some places they contain greenish rocks of sedimentary origin as for example at Edwards Find in the Yilgarn Goldfield and Boogardie in the Murchison Goldfield. These sedimentary "greenstones" are important since sedimentation structures in them, often only visible on examination with the microscope or on polished surfaces, may provide the key to the sequence in these stratified successions. Comparatively few sedimentary greenstones have been mentioned in the literature. Officers of the West Australian Geological Survey in recently published logs of diamond drill holes (e.g. *Bull. Geol. Surv. W. Aust.* 112) frequently record "clastic greenstones" but in the absence of petrographic information or more specific nomenclature it is impossible for the reader to understand much about either the present or the original nature of these rocks. The use of the terms "clastic greenstone," "metaclastic greenstone," "sedimentary greenstone," and "meta-sedimentary greenstone" by the same author for rocks from the same drill-hole would appear to indicate some difference between the clastic and sedimentary greenstones.

The presence of green sediments (such as green chloritic sandstones and shales) interbedded with lava flows and pyroclastic beds points to the necessity for more detailed stratigraphic work on these Precambrian rocks than

has been carried out in the past. To my knowledge no detailed stratigraphic study of the Older Greenstones has been made other than that recently completed by D. J. Forman (1960) on the greenstones of the country in the vicinity of the Hill 50 Gold Mine at Mt. Magnet. Finucane and Jensen (1953, p. 96) in describing the structure of the Kalgoorlie Goldfield say "Detailed mapping, coupled with increased knowledge of the contained sedimentary horizons, might lead to a clearer definition of the various flows comprising the Older Greenstones, but this work has been beyond the scope of most mining geologists in Kalgoorlie. Moreover, the economics of the great amount of work entailed are doubtful." To this I would say that the Kalgoorlie ore deposits have been studied now for more than half a century and we still do not know why these ore deposits occur at this locality. I feel that more detailed stratigraphic, petrological and mineralogical studies may yet give us this information and when we know the answer to this problem then we will be in an infinitely better position to know where we should search for further ore-bodies. This holds, of course, not only for Kalgoorlie, but for all of the West Australian Goldfields.

The greenstones of the Kalgoorlie District, as I have indicated, have been strongly folded. This deformation must have taken place at

during the past 50-odd years we still do not know why the Golden Mile ore-bodies occur where they do—in a “smaller but related structure on the eastern flank of the main structural disturbance” as Campbell (1953, p. 93) describes it. We do not know whether the Golden Mile mineralisation is related to a granitic parent magma (as generally supposed) or whether it is related to the Younger Greenstone magma (as I dared to suggest some fifteen years ago (Prider 1948, p. 63)). It may be that the current age-determination work may yield the answer to this question.

Coming back more specifically to the “greenstones”: I have indicated that our knowledge of the goldfields greenstones is very meagre and that there has been little addition to our knowledge of these rocks over the last 30 years in spite of the fact that extensive mining operations and diamond drilling programmes, both private and governmental, have offered us an abundance of material to work on. This is due to the lack of first-class petrological work on these rocks—to the fact that during this period there has been no qualified petrologist on the staff of the Geological Survey Branch of the Mines Department which is actively engaged in mapping the goldfields areas and carrying out diamond drilling programmes. I am not belittling the work of the field geologists of the Geological Survey. It will be apparent to all that the greenstones are very varied in origin, for the most part difficult to determine with surety and, in the mining areas where they are of greatest interest, they have generally suffered low grade metamorphism and extensive metasomatism which further obscures their origin. When dealing with such rocks as these, the field geologist needs a specialist petrologist to guide him. It is my belief that the appointment of a highly qualified petrologist to the staff of the Geological Survey would double the efficiency of every member of the field geological staff, bring us a long way towards putting order into the greenstone chaos of which I have spoken this evening, and, what is most important so far as the mining man is concerned, go a long way towards finding more ore.

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comparatively shallow depths under low temperatures as the rocks have not been recrystallised. They contain relicts of their original texture which enable us to determine their origin. In some places, however, the Archean greenstones have been more highly metamorphosed and are now represented by completely recrystallised metamorphic rocks such as hornblende schist (as in the Yilgarn Goldfield) and coarse hornblende granulite (as in the Wheat Belt). In these more highly metamorphosed rocks recrystallisation tends to obliterate the primary textures so that only the larger structures such as amygdules and pillows remain and at the highest grades of metamorphism even these disappear. I have already noted in my Address to this Society in 1945 how the grade of metamorphism appears to vary according to the distance from the margins of the greenstone belt and also according to the size of these greenstone areas (Prider 1948, p. 58). Thus the greenstones at Kalgoorlie which lie in the centre of an area of 8,000 square miles of greenstones have suffered lower grade metamorphism than those at Coolgardie and Gibraltar which are near the margins of this large greenstone area. Again, the Yilgarn Goldfield is a much smaller body of the Archean greenstones and has been more highly metamorphosed than the Kalgoorlie area and the greenstones are represented by various plagioclase-hornblende schists in which relict pillow structures may be seen in places. Still farther west, in the Wheat Belt, the areas of greenstone are even smaller and much more highly metamorphosed. Here we come to the higher amphibolite and granulite facies where the original structures, both megascopic and microscopic, have been largely obliterated by recrystallisation under high temperature-high pressure conditions to yield coarse plagioclase-hornblende schists and granulites, plagioclase-hornblende-pyroxene granulites and charnockitic granulites (Wilson 1959, p. 499). A notable feature is the occurrence of meta-jaspilites associated with these granulites. It is impossible to determine whether the basic granulites were originally extrusive basic volcanics (basalts and agglomerates), basic igneous intrusions or basic sediments such as greywackes, but the associated jaspilites are strong evidence that originally they were similar to the sequences developed in the various goldfields areas further east. Indeed, so far as we can say at the present, they are the representatives in the western part of the Shield of the Archean greenstones of the goldfields areas.

The Late Precambrian Greenstones

Included here are those rocks which have been referred to as "greenstones" which are younger than the granites of south Western Australia. They fall into two groups:—

- (a) The basaltic lavas interbedded with the sediments of the Proterozoic Nullagine System and
- (b) The altered basic igneous intrusives into the granites and Nullagine System.

There is but little information available concerning the basaltic rocks interbedded with the Nullagine sediments. They have been recorded

from a number of localities such as Braeside in the Pilbara, the Warburton Ranges near the South Australian border and from the Darling Scarp where the Cardup Shale contains a conformable albite-chlorite epidiorite sill or flow which is older than the dolerite dykes of this area (Prider 1941, p. 43).

The younger group is represented by altered dolerite dykes which have been intruded into all of the Precambrian rocks, including the Nullagine sediments. Earlier writers generally referred to these as "greenstone" dykes but more lately they have been described generally as dolerites or epidiorites. These dolerites have often been so completely uralitised that they are indistinguishable from the uralitised quartz dolerites of the Younger Greenstones of the goldfields areas. Indeed the epidiorites of the Darling Range near Perth can be matched in everything except age, with representatives of the Younger Greenstones of many mining fields. There have been no further contributions to our knowledge of these rocks since the publication of my 1945 Address other than my work (Prider 1958) on the quartz dolerite dyke swarm of Galena near Northampton.

The main economic significance of these late Proterozoic or early Palaeozoic basic dyke intrusions is that they are quarried for road metal and concrete aggregates. They appear also to be genetically related to the lead ore deposits of Northampton and Galena and various places in the Darling Scarp where small uneconomic deposits of lead ores occur. Their economic significance in auriferous areas is that they commonly cut and displace the ore bodies, and careful study of them may aid location of the displaced sections of such ore bodies.

Conclusion

Archean greenstones are the most important country rocks of the auriferous deposits which have played such an important role in the development of this State. I am very disturbed that my readings have led me to the conclusion that our knowledge of these rocks is very meagre. While a good deal of valuable work has been done on the granulite facies greenstones of the Wheat Belt there have been very few worthwhile contributions made to our knowledge of the goldfields greenstones during the past thirty years other than those of Wilson (1952) and Woodall (1954). Mining geologists have, by and large, focussed their attention on the ore-body and have tended to overlook the significance of the country rocks and the information they may afford concerning the genesis of the ore-body. It seems to me that emphasis in connection with ore search has been placed entirely on geological structure as mapped from drag folds and related tectonic structures without any detailed consideration of the lithology. I believe structure to be of great importance but I also believe that if we know more about the greenstone country rocks we shall be better able to map structure and interpret its significance in the formation of the ore-body. Equally important is the information that research may yield concerning the origin of the ore-body. I have already pointed out that in spite of intensive work

2.—*Crinia insignifera* Moore (Anura: Leptodactylidae) on Rottnest Island

By A. R. Main

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A population of *Crinia insignifera* Moore occurs on Rottnest Island. This species is polymorphic but only two (ridged and lyrate) of the three or possibly four morphs (ridged, lyrate, warty, smooth) known from the mainland occur on the island. It is suggested that the polymorphic characters are a simple Mendelian system and on Rottnest one homozygote is lethal. The frequency of the polymorphs in a local Rottnest population is traced from 1955 to 1960. Morph frequencies remain unchanged until the dry winter in 1959 when a significant change in frequency occurred. The change is possibly related to the seasonal conditions. Estimates of population size were made at the time morph frequencies were scored. These estimates indicate a considerable fluctuation in population size.

The findings are discussed in relation to the depauperate frog fauna found on Rottnest and the possible advantages of the ridged morph under the dry conditions of 1959.

Introduction

The granular-bellied species of *Crinia* (the *signifera* and *insignifera* super-species (Main, Lee and Littlejohn 1958) plus *C. georgiana*) exhibit a considerable variability in dorsal skin pattern. Quite recently some taxonomists (e.g. Loveridge 1935) treated these morphological variants as species. However, Parker (1940) recognised that similar variants occurred in all the granular bellicd species and (op. cit. p. 80) associated pattern and skin texture with names as follows: smooth uniform, *affinis*; striped, *stolata* or *ignita*; and irregularly marbled and warty, "typical" form.

Moore (1954) was the first author who referred to the foregoing phenomenon as polymorphism. Main (1957) distinguished four "morphs" as follows:—"ridged" for *ignita* or *stolata*; "smooth" for *affinis*; "lyrate" for *typical*; "warty" for animals with warty dorsum and lacking ridges. A thorough examination of polymorphism in mainland species is a long term project. The data available so far indicate that the phenotypes ridged and lyrate are genetically distinct but they do not indicate whether warty is also distinct. Furthermore, in some cases it is difficult to distinguish the smooth and warty phenotype. Clearly the basis for distinguishing the phenotypes can only be obtained by breeding several generations and at present this has not proved practicable.

The foregoing applies to mainland populations. There are, however, populations of *Crinia insignifera* Moore on Rottnest Island and, as will be seen below, these offer a simpler situation for a preliminary analysis of such aspects as inheritance, fecundity, viability, yearly changes in morph frequency, and population size.

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Taxonomic Status of Rottnest Island Populations

Morphologically the island animals are similar to those from the adjacent mainland. Main (1957) has reported a number of crosses between the island and mainland populations of *C. insignifera* which he interpreted as indicating absence of marked genetic incompatibility between them. A further series of 4 pairs of crosses have been made between Rottnest Island frogs and those from Seaforth and Attadale on the mainland. In each pair of crosses the same female was used, in one cross of the pair the male was from the same locality as the female (control cross) while in the other (experimental cross) it was not. In the control crosses a total of 274 eggs was used and in the experimental 314. There was no significant difference in the number of larvae hatching from the experimental crosses compared with the controls thus the results of these crosses support the earlier conclusions.

Littlejohn (1960) has reported his analysis of male calls and finds no differences. These findings suggest that the island population should be regarded as specifically the same as that of the adjacent mainland.

Nevertheless, despite the absence of behavioural or genetic barriers to gene flow there is one difference between the island and the mainland populations, and this is the absence of "warty" and "smooth" (patternless) animals from the island population. This observation has remained true for a number of years and has been repeated by many observers.

Inheritance of Polymorphic Characters

In all crosses so far made in which both parents were ridged, the offspring have been ridged. This phenotype must therefore be homozygous for the genetic factors determining dorsal pattern. Furthermore, ridged cannot be dominant. In Table I, are presented results of two crosses which can be interpreted if it is

TABLE I

Mendelian segregation of phenotypes in F_1 of two *in vitro* crosses of *C. insignifera* from Rottnest Island.

| Mating No. | Parents | | Ratio expected | Offspring | |
|------------|---------|--------|----------------|---|--------|
| | ♀ | ♂ | | Ridged | Lyrate |
| 470 | ridged | lyrate | 1 : 1 | 21 | 18 |
| 472 | lyrate | lyrate | 1 : 2 : 1 | 6 | 16 |
| | | | | 10 neither ridged nor lyrate died before metamorphosis complete | |

assumed that the lyrate phenotype is heterozygous. Mating 470 gives the expected 1 : 1 ratio when the homozygote and heterozygote are mated, while 472 gives the expected 1 : 2 : 1 ($\chi^2 = 1.0$ p < .7 > .5) when both parents are heterozygous. This interpretation assumes that the 10 animals which died at a stage when the ridged or lyrate pattern would have been apparent were neither ridged nor lyrate but patternless and lethal. While the foregoing seems to be an adequate explanation for the Rottnest population, it does not at present offer a satisfactory explanation for mainland populations in which the warty phenotype occurs. When warty animals are used in crosses, some of the offspring are ridged so the warty phenotype is either the lyrate genotype with poor penetrance, or another allele of the ridged locus or an epistatic gene is involved. The selection of the interpretation which satisfactorily accounts for the inheritance among mainland *C. insignifera* requires the rearing and mating of an F₁ generation. Nevertheless, it is possible to take advantage of the apparent genetic simplicity in the Rottnest population and proceed with an analysis of the population assuming that one gene and one allele is involved and that one homozygote is lethal, so that there are only two genotypes and two phenotypes in the population.

Fecundity, Viability and Vigour

Table II presents information collected to date on the number of eggs per morph for Rottnest and Attadale. The number of eggs per morph

TABLE II

C. insignifera, Rottnest and Attadale, mean number of eggs per morph (1956 and 1957 combined).

| Locality | Ridged | Lyrate | Patternless |
|----------|------------|--------------|-------------|
| | N. Mean | N. Mean | N. Mean |
| Rottnest | 4 191 ± 31 | 4 176 ± 45 | ... |
| Attadale | 8 122 ± 54 | 15 98 ± 43.5 | 12 142 ± 51 |

on Rottnest is not significantly different between ridged and lyrate phenotypes with the small numbers available. Also, the differences between the three phenotypes at Attadale are not statistically significant. There appears to be a considerable difference between Attadale and Rottnest. Differences between these localities were very marked in 1957. However, more data collected during the dry year 1959 tended to raise the mean values for Attadale to ridged 156, lyrate 117. An analysis of variance shows that, for the Attadale population, differences between morphs in the average number of eggs produced per female are not significant. When all data for each locality are combined the average number of eggs per female is: Attadale 134, Rottnest 183. Analysis of variance shows that this difference is significant at the level p < 0.05 > 0.01.

How much biological significance should be attached to this result is uncertain because large (i.e. old) females produce more eggs than young ones which means that in years in which numer-

ous females are breeding for the first time the average number of eggs per female may be small, whereas in years in which few females are breeding for the first time, i.e. there is a high proportion of large old animals (reflecting the poor recruitment resulting from low breeding success in a previous year) the average number of eggs per female may be high.

Crosses carried out and reported earlier (Main 1957) were terminated at the time of hatching of the larvae. More recent breeding experiments (see above) have been continued after hatching. At hatching, the crosses between Rottnest and mainland localities produced slightly smaller offspring than the comparable control. This relationship held in all pairs as the larvae grew except one in which the control cross (lyrate female x ridged male) was much smaller and showed developmental defects such as absence of limb buds, mouth and intestine. None of this cross survived to metamorphosis which suggests that a lethal combination is present in the Rottnest population. However, it is not expressed when eggs of the same female are mated to an Attadale male so a genetic interaction is indicated rather than any abnormality in the eggs. During the 1960 winter this cross has been repeated. At 28 days post hatching no developmental defects as described above are apparent and in length and developmental stages the experimental crosses are comparable with the controls.

The 1960 larvae need to be raised to metamorphosis in order to confirm that they are completely normal but the results suggest that the earlier abnormal larvae were due to an experimental error.

Changes in Morph Frequency

During the dry season (November to April) Crinias are cryptozoic and restricted to the very few sites where there is sufficient cover. In many localities it is impossible to locate any animals despite the fact that very large breeding congregations are formed in these same sites during the breeding season. Fortunately on the north-east side of the Lighthouse Soak (see map in Hodgkin & Sheard (1959)) an area of *sporobolus virginicus* with a large number of small rocks harbours an unknown fraction of the soak population of *C. insignifera* and these have been scored for morph frequency with the results shown in Table III.

In the table sexes have not been distinguished because neither the pre-breeding adults nor the juveniles in the post-breeding populations can be certainly sexed on externals. The data available (unpublished) indicate that, for the Rottnest population, there is no difference in polymorph frequency between the sexes. From 1954 to 1959 the morphs do not differ significantly from equality. However the morph frequencies show a consistent excess of ridged over lyrate animals except in the 1959 pre-breeding population when the two morphs are equally frequent. The post-breeding 1959 population does, however, differ significantly from equality (p < 0.02 > 0.01).

There is no reason to believe that the morph frequencies should be equal and it is more

meaningful to test whether subsequent samples differ significantly from the immediately preceding samples. This has been done with the results shown in the column headed significance in Table III. The changes do not reach statistical significance until post-mating 1959.

TABLE III

Crinia insignifera, Rottnest Island. Frequency of each morph present.

| | Frequency | | Significance | |
|--|------------|--------|--------------|----------------|
| | Both sexes | | χ^2 | P |
| | Ridged | Lyrate | | |
| 1954— Rottnest: material added to collection | 20 | 14 | | |
| | | | 0.08 | < .8 > .7 |
| 1955— Lighthouse Soak (scored in field): Pre-breeding | 43 | 34 | | |
| Post-breeding | 126 | 114 | 0.262 | < .7 > .5 |
| 1956— Lighthouse Soak: | | | 0.931 | < .5 > .3 |
| Pre-breeding | 26 | 17 | | |
| | | | 0.892 | < .5 > .3 |
| 1959— Lighthouse Soak: Pre-breeding | 49 | 50 | | |
| Post-breeding | 54 | 25 | 6.45 | < .02 > .01 |
| 1960— Lighthouse Soak: Pre-breeding | 41 | 24 | 0.439 | .5 |

The change in morph frequency between pre- and post-breeding 1959 is significant ($p < 0.02 > 0.01$) and it is possible that these changes are related to the seasonal weather. The 1959 season was warmer and drier than usual, June was the warmest since 1949, July had the highest mean maximum temperature ever recorded and August was the warmest ever recorded. On Rottnest in the period May to September the average rainfall is about 24 inches, but during 1959 it was 7 inches below average.

At Perth the season was also drier than usual but the cloudiness was not much reduced. However, with higher air temperatures and reduced rainfall, water levels in ponds were lower, with a consequent rise in temperature. Minima and maxima were measured on Lighthouse Soak on two occasions, viz., August 15-16 and September 28-29; both minima were 54°F and maxima 71° and 73° respectively. In normal years the maxima are about 10°F lower while the minima are in the vicinity of 50-54°F. In view of the foregoing it seems likely that the change in morph frequency between the pre-breeding and post-breeding population is in some way related to the success of the ridged morph under warmer conditions.

Population Size

Estimates of the size of discrete local populations is possible under two circumstances:

- (a) During the dry season when the animals are aggregated in a way that allows sampling (see above).

- (b) When water is present and malcs have formed a breeding congress.

Sampling and estimation are not possible when water is present but conditions are otherwise unsuitable for breeding as the population is then dispersed.

The size of the population on Lighthouse Soak during the dry season has been estimated by toe clipping in a capture, mark, release and recapture procedure. The data are arranged in a manner suggested by Hayne (1949). The formula $P = \frac{\sum wx^2}{\sum wxy}$ (where P is population estimate) permits an average of the data and yields a population estimate. For the post-breeding population in 1955 the data of Table IV yields a population estimate of 1,021. No further

TABLE IV

Lighthouse Soak, Rottnest—Census data pertaining to the population of *Crinia insignifera*, November, 1955.

| Date | Number of captures | | | Proportion of catch previously handled (y) | Total number previously marked (x) |
|----------|--------------------|-------------------|---------------|--|------------------------------------|
| | New | Previously marked | Total No. (w) | | |
| 16/11/55 | 65 | 0 | 65 | 0.00 | 0 |
| 18/11/55 | 67 | 7 | 74 | 0.094 | 65 |
| 20/11/55 | 64 | 7 | 71 | 0.099 | 132 |
| 21/11/55 | 18 | 6 | 24 | 0.250 | 196 |
| 24/11/55 | 26 | 6 | 32 | 0.19 | 214 |

estimates were possible until 1959 when data obtained from the pre-breeding population (Table V) yields an estimate of 138. The post-breeding population was sampled and the data

TABLE V

Lighthouse soak, Rottnest—Census data pertaining to a population of *Crinia insignifera*, March, 1959.

| Date | Number of captures | | | Proportion of catch previously handled (y) | Total number previously marked (x) |
|---------|--------------------|-------------------|---------------|--|------------------------------------|
| | New | Previously marked | Total No. (w) | | |
| 17/3/59 | 47 | 0 | 47 | 0.00 | 0 |
| 18/3/59 | 33 | 15 | 48 | 0.31 | 47 |
| 19/3/59 | 19 | 28 | 47 | 0.60 | 80 |

(presented in Table VI) yield a population estimate of 261 animals. The pre-breeding population data for 1960 yields an estimate of 86 animals (Table VII).

TABLE VI

Lighthouse Soak, Rottnest—Census data pertaining to a population of *Crinia insignifera*, November, 1959.

| Date | Number of captures | | | Proportion of catch previously handled (y) | Total number previously marked (x) |
|----------|--------------------|-------------------|---------------|--|------------------------------------|
| | New | Previously marked | Total No. (w) | | |
| 18/11/59 | 6 | 0 | 6 | 0.00 | 0 |
| 21/11/59 | 10 | 0 | 10 | 0.00 | 6 |
| 22/11/59 | 40 | 2 | 42 | 0.05 | 16 |
| 23/11/59 | 21 | 6 | 27 | 0.22 | 56 |

TABLE VII

Lighthouse Soak, Rottnest—Census data pertaining to a population of *Crinia insignifera*, March, 1960.

| Date | Number of captures | | Total No. (w) | Proportion of catch previously handled (y) | Total number previously marked (x) |
|---------|--------------------|-------------------|---------------|--|------------------------------------|
| | New | Previously marked | | | |
| 8/3/60 | 32 | 0 | 32 | 0.0 | 0 |
| 9/3/60 | 18 | 10 | 28 | 0.36 | 32 |
| 10/3/60 | 15 | 22 | 37 | 0.59 | 50 |

In the absence of an estimate of population size based on a breeding congress to check on the above, it would be unwise to consider the foregoing as estimates of the total population because an unknown fraction of the population may be in hiding in undetected places other than stones. Nevertheless, the stones under which the animals are hiding during the dry season have remained constant in number and apparently favourable environmentally because frogs are always found beneath them so it seems reasonable to accept the estimates but interpret them as indicators of the population size over the years.

These estimates indicate a considerable fluctuation in the size of the population on Lighthouse Soak. It is unfortunate that no estimate is available for the pre-breeding 1956 population. Nevertheless it appears that as the population declined from the high numbers of November, 1955 to the low numbers of March, 1959 so the frequency of the ridged morph decreased in the population. The recruitment from breeding in 1959 reversed this trend with the result that at the end of the year ridged animals were twice as abundant as lyrate animals. This change is probably associated with the selective advantage possessed by ridged animals under warmer conditions as discussed in the previous section. In the 1960 pre-breeding populations the excess of ridged animals was maintained (Table III) suggesting that there had not been a strong selection against ridged adults during the period November, 1959–March, 1960. However, during this period deaths had occurred as indicated by the population estimates.

Discussion

Storr, Green and Churchill (1959, p. 70) have shown that the vegetation of Rottnest was once like the tuart woodland of the adjacent mainland but has subsequently changed to a coastal complex. On the mainland from the littoral to the eastern boundary of the tuart woodland ten species of frogs are known to occur. Reasoning from the floral information cited above, all the frogs of the tuart zone could be expected on Rottnest. However, only three, viz. *Crinia insignifera*, *Hyla moorei* Copeland, and *Heleioporus eyrei* (Gray) occur on the island while seven, viz. *Hyla adelaidensis* Gray, *Limnodynastes dorsalis* (Gray), *Crinia glauerti* Loveridge, *C. georgiana* Tschudi, *Pseudophryne guentheri* Boulenger, *Neobatrachus pelobatoides* (Werner), and *Myobatrachus gouldii* (Gray) do not.

The foregoing would indicate that the faunistic diversity on the island has been reduced in a manner similar to the reduction among plants. Furthermore it seems that the genetic diversity within the *C. insignifera* population has been reduced, at least patternless morphs do not occur on the island where they may now be at a selective disadvantage.

Until the post-breeding sample of 1959 the data suggest that there was a system of balanced polymorphism operating on Rottnest. The increase in frequency of ridged animals during the 1959 breeding season suggests that this genotype has an advantage under the warmer and drier conditions which characterised this season.

The advantage enjoyed by striped morph may be due to

- more rapid development so that, as larvae, ridged animals can take advantage of more ephemeral waters in dry years.
- the larvae of the morph may be able to tolerate the warmer water temperatures which are found in warm dry seasons.

Both these possibilities are subject to experimental test under constant temperature conditions.

Further studies on the inheritance and genetic control of the morph patterns are desirable. However, the apparent small size of the lighthouse soak population makes it essential that no animals be removed lest interference affect the nature of the selective processes operating on the population. Additional matings can be made in years when the population size is large enough for the effect of removing animals to be reduced or negligible.

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3.—The Stratigraphy of the Moora Group, Western Australia

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This paper is an account of the stratigraphy, petrology, palaeontology and structure of the Moora Group sediments which outcrop along the western margin of the West Australian Shield between Moora and Coorow. The sequence which is believed to be Proterozoic or Lower Palaeozoic in age is formally subdivided into four formations as follows:

- (4) Coomberdale Chert (3,303 feet).
- (3) Mokadine Formation (330 feet).
- (2) Dalaroo Siltstone (500 feet).
- (1) Capalcarra Sandstone (160 feet).

The basal Capalcarra Sandstone unconformably overlies a crystalline basement of Archean age. Basement rocks and Moora Group sediments are intruded by quartz dolerite dykes of probable Upper Proterozoic or Lower Palaeozoic age.

The Moora Group is unfossiliferous apart from abundant stromatolites and one problematic organism of unknown affinities.

The major structural feature in the region is the Darling Fault and the Moora Group sediments occupy the shatter zone of this major rift. The sediments have been subject to west-block-down strike faulting along N.N.W. to N. trends and stratigraphic throws up to 1,500 feet have been calculated. The general structure is that of a fractured homocline in which the regional dip of the sediments is 15° W.S.W. to W.

Introduction

The oldest sedimentary sequences of the Perth Basin occur in narrow, north-trending belts of outcrop overlying the Precambrian shield along the eastern margin of the basin. The shield edge is formed by the major Darling-Urella Fault Zone and erosion of the rocks on the eastern wall of this structure has resulted in the preservation of a number of scattered exposures along the flank of the Darling-Urella Scarp from Mundijong in the south to beyond Yandanooka in the north. To date four sedimentary sequences (Fig. 1) have been recognised in this belt, these are: (1) the Cardup Shale, between Mundijong and Kelmscott, (2) the Yandanooka Group, east of Yandanooka and Arrino, (3) the Billeranga Beds, outcropping in the Billeranga Hills and (4) the Moora Group, between Moora and Coorow. This paper is the first detailed study of the Moora Group.

The Moora Group which was formerly considered as a southern extension of the Yandanooka Group (Campbell 1910 and Fairbridge 1950) was studied by the authors in 1955 and the results of this work were first submitted in thesis form as part of the requirements for the degree of Bachelor of Science with Honours in the University of Western Australia. A detailed

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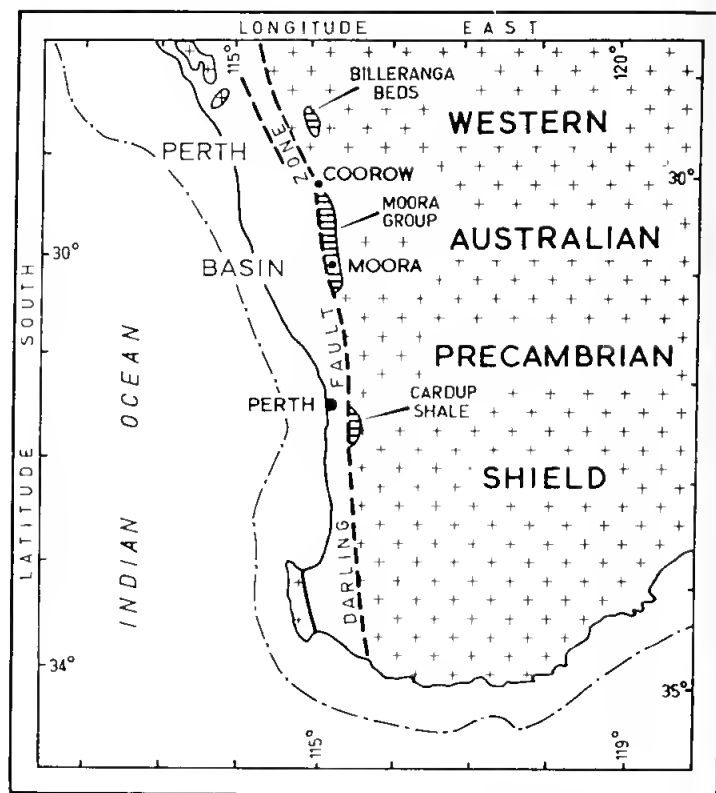


Fig. 1.—Locality map showing distributions of the Moora Group, Billeranga Beds and the Cardup Shale in relation to the larger tectonic features of south-west Western Australia.

map of 30 square miles of Moora Group outcrop between Moora and Coomberdale (Plate III) was prepared to illustrate the rock units present and the detailed geological structure of one part of the Moora Group outcrop. A reconnaissance survey of the exposure between Coomberdale and Yandanooka was also made to determine the areal extent and character of the formations defined in the Moora-Coomberdale area.

The Moora Group is a flat-dipping sequence of arkose, siltstone, orthoquartzite and chert lithologies overlying unconformably, a crystalline basement of Archean age. A stratigraphic subdivision into four formations is proposed herein. The sediment pile is predominantly a stable shelf association of orthoquartzite and silicified limestone (now chert). An initial period of instability and contemporary vulcanism accompanied the deposition of the lower formations of the group. Sedimentary structures and stromatolites indicate a shallow-water origin for the sequence with the palaeogeographic implication of marine transgression of the West Australian Shield from the Perth Basin to the west. The age of the transgression is in doubt; Proterozoic and Lower Palaeozoic ages have been

suggested by various authorities. Unfortunately the Moora Group is unfossiliferous apart from stromatolites of algal origin and one problematic fossil of doubtful affinities so that no palaeontological age determination is possible. A series of quartz dolerite dykes intrude the Moora Group; Prider (1952) has suggested an Upper Proterozoic "Nullagine" age for the dolerite intrusives of south-west Western Australia and if this is correct the Moora Group can only be Precambrian in age.

Other sedimentary sequences on the shield margin have been studied in some detail. The Cardup Shale is well known due to research from the Department of Geology, University of Western Australia (Prider 1941; Davis 1942; Thomson 1942; and Singh 1958). Woolnough and Somerville (1924) first named the Yandanooka Group (Series) and that sequence has since been examined by Baker (1951), Johnson, de la Hunty and Gleeson (1954) and Playford and Wilmott (in McWhae, Playford, Lindner, Glenister and Balne 1958). At the time of writing the Billeranga Beds are being studied (J. A. Lalor and P. A. Arriens, pers. comm.). Further detailed structural study is needed in the Yandanooka Group and in the northern outcrops of the Moora Group before the early geological history of the Perth Basin can be adequately interpreted.

Previous Work

Previous geological investigations dealing with the sediments at Moora and their northern continuations have been undertaken in connection with artesian water prospects, phosphate deposits in caves and oil prospects in the Perth Basin. Also three regional surveys have been conducted by the W.A. Geological Survey and there have been various brief reconnaissance surveys by the staff and graduate students of the University of Western Australia.

In 1898, Gibb-Maitland described the Moora Group rocks as "a low range of massive quartzites" rising from the flats east of Moora, forming "a portion of the western escarpment of the tableland drained by the head of the Moore River." At this time Gibb-Maitland was unaware of the presence of the Darling Fault and suspected that the Archean rocks and associated "quartzites" continued to the west under a sedimentary onlap. Montgomery (1909) observed impure limestone at the bottom of Jingemia Cave near Watheroo and described surrounding rocks as quartzite and "metamorphic sandstone." Strata at Arrino and Yandanooka, lithologically similar to siltstones at Moora, were described by Campbell (1910) as "quartz conglomerates and submarine tuffs." Campbell noted that "... representatives of this series are first met with near Moora, whence they extend as a continuous strip, as yet undefined northward as far as Greenbrook ... having been noticed and examined at Jingemia, Coorow, Carnamah, Three Springs and Arrino ...". Blatchford (1912) briefly described the Archean basement to the east as being "... usually gneissic in character" and observed that dolerite is intruded into the overlying "quartzites." Saint-Smith (1912) proposed the name

"Darling Fault" for the major dislocation which follows the Darling Scarp north along the western margin of the Western Australian Shield.

In 1914 a bore was drilled 2½ miles west of the railway line at Moora to a depth of 2,200 feet in an endeavour to find an artesian water supply for the town. Jurassic plant fossils were identified in samples from various beds from 665 to 1,200 feet below surface. No fossil material was recognised in samples from the bottom 1,000 feet of the hole (Foreman 1935).

This bore indicated that the fault was somewhere between the sediments east of Moora and the bore-site. Subsequent geophysical work showed that the fault passes very nearly under the townsite of Moora (Thyer and Everingham 1956).

Woodward (1915) suggested that the upper cherty rocks of the Moora sequence originated when carbonate rocks were replaced by silica. More recently, Fairbridge (1950) ascribed the undulose lamination found in chert blocks near Gunyidi (north of Moora on the Geraldton Highway) to algae and identified the genus *Collenia*. At this time the strata east of Moora together with the Yandanooka Group to the north and the Cardup Series (Cardup Shale) to the south were generally considered by local geologists to be late Proterozoic in age because of their supposedly unfossiliferous nature and the presence of dolerite dykes which were considered to have been intruded during late Proterozoic or early Cambrian times (Prider 1948).

A survey of the Perth Basin, including the area of outcrop of the Yandanooka Group and Cardup Shale was carried out by West Australian Petroleum Pty. Ltd. between 1951 and 1957. The results of this survey are detailed in McWhae *et al.* (1958); this paper also contains brief descriptions of the formations of the Moora Group together with their distribution and their probable relation to the Yandanooka Group and Cardup Shale.

Physiography

The Moora Group occurs immediately to the east of the major Darling Fault dislocation which forms the western edge of the West Australian Plateau or Peneplain. The topographic expression of the fault is the Darling Scarp, a prominent meridional feature formed by the uplift of the shield relative to the Perth Basin on the west and by the erosion of the uplifted margin along the fault. South of Moora the scarp is high (1,000 to 1,500 feet above sea level) and fronted by the resistant crystalline rocks of the shield proper; here the plateau rim is dissected by numerous youthful streams. The scarp becomes less prominent from Moora north where the Moora Group sediments form the present scarp face. In this tract the plateau rim reaches altitudes of 800 feet above sea level but the topographic elevation above the alluvial piedmont is only in the order of 200 feet. The Moore River, Kiaka Creek and other streams crossing the scarp in the Moora-Coorow tract are mature with wide alluvial valleys. The dissected terrain grades eastwards into the old landscape of the peneplain proper.

The courses of minor streams in the Moora Group outcrop have been determined by three main factors. First, the homoclinal west dip of the sediments and the variable resistance to erosion of the strata; the result has been the development of north-south valleys between strike ridges of chert and resistant orthoquartzite. Second, the dolerite dykes are highly susceptible to erosion and gullies are developed along the strike of most dykes. Third, streams tend to follow fault zones where crushing and jointing have allowed faster erosion by running water.

Laterite and siliceous duricrust are widespread being sometimes overlain by sand or sandy soil with laterite pebbles. The thickest development of duricrust has taken place above or adjacent to dolerite dykes, but all rock types are susceptible to this type of weathering. The presence of laterite *in situ* on the valley flanks near the scarp suggests that at least some rejuvenation along the Darling Fault occurred before the time of laterite formation.

In general, the groundwaters beneath the chert country are potable, and those underlying the flats to the west of the scarp are brackish (Blatchford 1912).

The Moora Group

The Moora Group outcrops in a narrow, north-trending belt about the 116° E meridian between Moora (latitude 30° 38' S) and Coorow (latitude 29° 55' S). The northern continuation of the sediments is obscured by superficial Quaternary sands and the sequence has not been traced further north than Coorow (Fig. 1). The sediments occupy the fragmented terrain on the eastern wall of the Darling Fault shatter zone and unconformably overlie the Archean gneisses and granites of the West Australian Precambrian Shield; they form a homoclinal structure with a regional dip of 15° W.S.W. to W. The older basement complex is exposed to the east of the Moora Group while the western outcrop of the group is limited by a fault-line scarp formed by eastward erosion from the Darling Fault. The Darling Fault is the major structural feature of the region and forms the eastern boundary of the Perth Basin, a taphrogene with some 30,000 feet subsidence (Thyer 1951).

The Moora Group (Fig. 2) consists of four conformable formations of bedded chert, orthoquartzite, arkose and siltstone detailed as follows:

4. *Coomberdale Chert*: Bedded cherts, chert breccias, orthoquartzite, siltstone and rare dolomitic limestones. Thickness 1,890 to 3,300 feet.

3. *Mokadine Formation*: Tuffaceous and calcareous siltstones, arkoses and thin chert beds. Thickness 0 to 330 feet.

2. *Dalaroo Siltstone*: Siltstones, claystones, and arkose with thin chert beds. Thickness 370 to 500 feet.

1. *Capalcarra Sandstone*: Conglomeratic arkoses and orthoquartzites unconformably overlying a crystalline basement complex of granite and gneiss. Thickness 30 to 160 feet.

The Moora Group is extensively block-faulted with west-block-down displacement on a series of north-trending strike faults. Stratigraphic throws of approximately 1,500 feet have been measured. It is considered that the preservation of the sediments on this, the eastern, up-thrown block of the major Darling Fault is due to the west-block-down movement in the shatter zone to the east of the master rift.

Moora Group sedimentation was probably brought about and maintained by warping of the shield margin in response to even greater downwarping in the geosyncline area to the west. Available structural evidence indicates that the Moora Group phase preceded the formation of the major Darling Fault dislocation, although Prider (1952) suggests that this was a line of crustal weakness as early as Archean times with west-block-south transcurrent movement. There is little evidence for transcurrent movement in the post-Moora Group faults which are of the gravity type. Pre-Moora Group movements of the Darling Fault may have been dominantly transcurrent.

The Capalcarra Sandstone, the lowermost unit of the group, is characteristically a discontinuous basal sand formed by the winnowing under strand-line conditions of a weathered rock mantle (regolith) derived from the crystalline Archean basement. Instability and seismic activity during deposition of the Capalcarra Sandstone is implied by the sandstone dykes of Capalcarra material which are intruded into the basement granites in the Watheroo area (Logan 1958). The Dalaroo Siltstone and Mokadine Formation contain detrital volcanic material and feldspars as indices of vulcanism and instability within the craton area following the initial transgression. The thick Coomberdale Chert is a stable shelf association of limestone (now chert) and orthoquartzite with abundant evidence of shallow-water origin in ripple marks, mud cracks, cross-bedding, oolites and algal stromatolites. Such a lithofacies aspect is normally developed when slow uniform subsidence of the depositional interface is accompanied by slow clastic and biogenic sedimentation.

The Capalcarra Sandstone

The Capalcarra Sandstone is a sequence of arkosic conglomerate and sandstone lying unconformably on the Archean crystalline basement. The formation has been recognised at Moora and Watheroo. "Capalcarra" is the name of a homestead and property on the north side of the Miling Road, approximately 1½ miles east of Moora. The type section has been taken from an area east of Mokadine Spring near Moora (30° 38' S; 116° 03' E). The estimated thicknesses given in the type section below are approximate due to poor outcrop of the formation.

Dalaroo Siltstone

Gray silty claystone.

Capalcarra Sandstone

| | Thickness (Feet) |
|--|---------------------|
| 4. Very fine-grained arkose. Not exposed <i>in situ</i> . Spec. 36722.* | 25 |

3. Strongly metasomatised rock whose original texture is not apparent. Affected by adjacent dolerite intrusions, no solid outcrop, rare cobbles in red loamy soil 55
 2. Orthoquartzite. Occurs as rare cobbles in red loamy soil. Coarse-grained, well-sorted, with low porosity, cement microcrystalline quartz. White to gray, orange on weathered surfaces. Rare kaolinised feldspar grains present. Spec. 36720 40
 1. Conglomeratic arkose. Solid outcrop poor, weathered. Medium- to coarse-grained, pink, poorly-sorted, containing angular pebbles of acid crystalline rock, grains of quartz and feldspar. Specs. 36712, 36719, 36716. 40
- Estimated total thickness of Capalcarra Sandstone in type locality, 160 feet.

Archean Basement

Crystalline complex of granite and acid gneiss.

The Capalcarra Sandstone is 160 feet thick in the type section at Moora and only 30 feet thick at Watheroo. The Watheroo section is complicated by strike faulting and the thickness may well exceed that measured. No other outcrops of the formation were discovered in the reconnaissance survey conducted between Watheroo and Coorow. Orthoquartzites of the Capalcarra Sandstone are intruded into the Archean granite basement at Watheroo to form clastic dykes (Logan 1958). The suggested emplacement mechanism is by slumping of unconsolidated Capalcarra sands into basement fissures and the dykes imply instability during or following deposition of the Capalcarra Sandstone.

Petrography.—The Capalcarra Sandstone is dominantly composed of conglomeratic arkose but minor orthoquartzite and silty sandstone members are developed in the formation.

The conglomeratic arkose is a pink to gray rock composed of poorly sorted, sub-angular to sub-rounded detrital grains of quartz, feldspar and fragments of granitic rocks. There is often a matrix of variable amounts of hematite, sericite, clay and microcrystalline quartz. The orthoquartzite members are usually pink, medium-grained clastics with well-rounded detrital quartz grains and minor amounts of detrital feldspar. The silty sandstones are made up of a poorly sorted admixture of quartz, microcline, plagioclase, muscovite, biotite and composite grains of the same minerals in a matrix of microcrystalline quartz, sericite and iron oxides. Secondary overgrowth of quartz on detrital quartz grains is common throughout the formation.

The Dalaroo Siltstone

The Dalaroo Siltstone is a sequence of claystone, siltstone, arkose, chert and tuff which conformably overlies the Capalcarra Sandstone. At Moora and Coomberdale the formation is overlain by the Mokadine Formation and at Watheroo by the Coomberdale Chert. Basal units of the formation are exposed at Namban. The name is taken from Lake Dalaroo, a large claypan 3 miles west-north-west of Moora. The type section is situated 1½ miles east of Moora townsite, ½ mile east of Mokadine Spring (30° 8' S; 116° 03' E). The lower part of the type

section shows no exposure *in situ*. An estimate of the sequence of lithofacies and the approximate thickness of units was made by traversing the pebbly outcrop in the direction of dip and taking representative samples. The upper part of the section is more or less affected by lateritisation, and some parts of it are sheared to a low grade of metamorphism.

The type section of the Dalaroo Siltstone is as follows:

Mokadine Formation

Pale red, massive, cross-bedded, medium-grained arkose. Grains rounded. Conformably overlying the Dalaroo Siltstone.

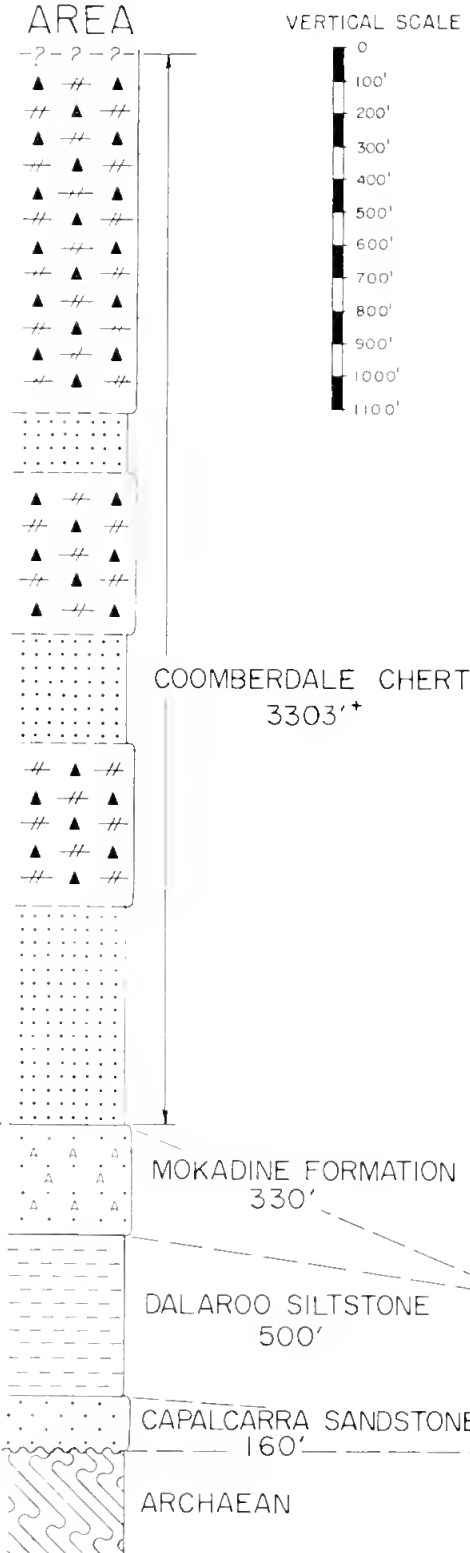
Dalaroo Siltstone

- | | Thickness
(Feet) |
|---|---------------------|
| 13. Tuffaceous, sandy siltstone. Outcrops as boulders and flaggy blocks. Has micro current-bedding and ripple markings. In some places is interbedded with beds of very fine-grained arkose, similar to the lowest member of the Mokadine Formation. A lens of massive chert, three feet thick, is present in one part of the locality. The sand-size grains of the siltstone are of feldspar and devitrified volcanic glass. Spec. 36785, 36784 11 | 11 |
| 12. Yellow to very dark red, tuffaceous, silty and sandy claystone, outcropping as small cobbles and angular blocks. Exhibits fine graded-bedding in thin section. Subconchoidal fracture present in hand specimens not affected by faulting (those which are affected show fracture-cleavage). Devitrified volcanic glass particles are present in the sand and silt fraction and the unit is possibly in part a waterlain tuff. Spec. 36782, 36783 68 | 68 |
| 11. Moderate-red fissile claystone interbedded with fine-grained siltstone (weathers yellow). Almost symmetrical ripple marks on one hand-specimen measured 2 cm between crests and were 2 mm in amplitude. Silty laminae contain quartz, saussuritised feldspar, biotite, muscovite, and iron-ore all in a siliceous cement. Spec. 36780, 36781 35 | 35 |
| 10. Yellow, gray and purple fissile claystone, interbedded with moderate -red, fine-grained fissile siltstone. Angular grains of quartz and feldspar, flakes of muscovite and biotite are main silt-sized components. Spec. 36780 20 | 20 |
| 9. Fine-grained, purple to gray fissile siltstone. Small-scale slumping evident. Main minerals of the silt grade are feldspar, iron-ore and muscovite. Spec. 36729 10 | 10 |
| 8. White chert. Stands out as a subsidiary ridge on the eastern slope of Mokadine Hill. Banded in parts. On weathered surfaces it is drusy and saccharoidal 6 | 6 |
| 7. Claystone. The outcrop has been bleached during the lateritisation process. Occasional quartz grains are all that show up in thin section. The hand specimen exhibits a pink banding 48 | 48 |
| 6. Gray-pink, medium to coarse-grained arkose. No outcrop <i>in situ</i> . In thin section, sub-rounded potash feldspar constitutes 50 per cent. of the rock. Larger rounded quartz grains surrounded by authigenic quartz outgrowths and fine angular grains of iron-ore, complete the assemblage. Spec. 36727 51 | 51 |
| 5. Massive gray-red silty claystone and quartzose granule conglomerate. The siltstone has good parting along bedding planes, and its silt-sized components are feldspar, muscovite | |

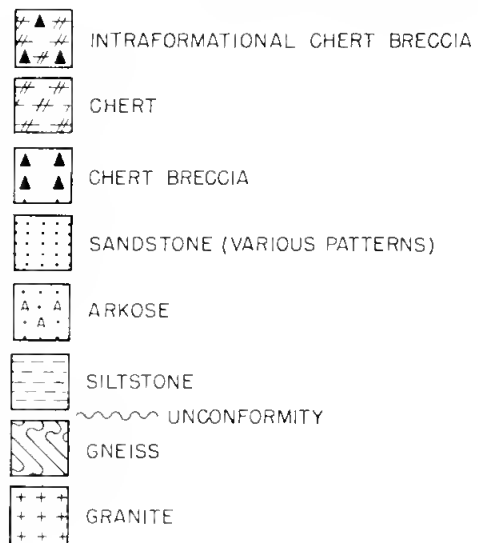
Specimen No. in Dept. of Geology, University of Western Australia.

THE MOORA GROUP COLUMNAR STRATIGRAPHIC SECTIONS

MOORA COOMBERDALE AREA



LITHOLOGY LEGEND



WATHEROO AREA

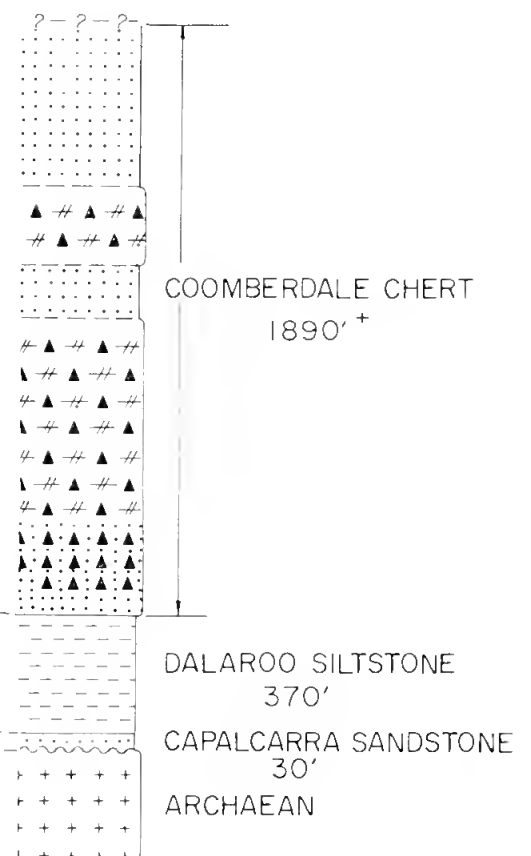


Fig. 2.—Columnar stratigraphic sections of the Moora Group at the type area (Moora-Coomberdale) and Watheroo.

and angular grains of iron-ore. The matrix of the granule conglomerate is too weathered for determination of its original content. The quartz granules are sub-rounded. The relationship of the two rock types in the unit is not discernible because of lack of solid outcrop, but the presence of the granule conglomerate may indicate that strata similar to the overlying arkose are present in this member. Spec. 36726

- | | | |
|----|---|----|
| 4. | Gray-red silty sandstone. No outcrop <i>in situ</i> . Friable cobbles in clayey loam. Contains dark red mudballs 1.5 mm in diameter and coarse grains of kaolinised feldspar and muscovite flakes. Spec. 36725 | 68 |
| 3. | Gray-red silty shale, weathering yellow and orange. No outcrop <i>in situ</i> . Individual laminae have constant thickness. Constituent minerals are clays and quartz | 25 |
| 2. | Moderate-red to light brown fine-grained arkose. No outcrop <i>in situ</i> . Surface debris largely kaolinised. A cement of authigenic quartz is present, also secondary chlorite and sericite. Spec. 36724 | 75 |
| 1. | Silty claystone. No outcrop <i>in situ</i> . In the area examined where debris from this unit is exposed, intrusion of dolerite dykes nearby has resulted in the formation of sericite and chlorite in the rock and the silicification of the joint planes. Silt-sized particles of quartz and feldspar are corroded. Spec. 36723 | 34 |
| | Estimated total thickness of the Dalaroo Siltstone, 500 feet. | 54 |

Capalcarra Sandstone

Very fine-grained arkose. Spec. 36722.

The thickness of the Dalaroo Siltstone ranges from 500 feet at Moora to 370 feet at Watheroo. The possibility of strike-faulting at Watheroo makes the value given here indefinite. At Coomberdale the basal units of the formation crop out to the east of the Noondine Fault, the section being 80 feet thick while the upper members outcrop west of the fault with a thickness of 360 feet.

The dominant rock types are siltstone and claystone containing quartz, feldspar and clay minerals. The Moora section contains 80% claystone and siltstone; the Coomberdale section 100% and the Watheroo section is composed of about 70% of these lithologies. Some units contain tuffaceous and detrital carbonate material. At the Coomberdale locality one unit which is certainly pyroclastic occurs in the upper part of the section immediately below the contact with the overlying Mokadine Formation. Undoubted tuffaceous siltstones also occur in the upper unit of the Dalaroo Siltstone at Watheroo. At this locality the upper units of the Dalaroo Siltstone crop out as resistant strike ridges trending 150°. The highest unit is a sequence of tuffaceous siltstone with lesser quantities of interbedded arenite and conglomerate. Cross-bedding, ripple marks (Fig. 3) and graded and lensing strata are common. Fragments of volcanic rock occur throughout and are associated with detrital carbonate in a number of beds. Rare conglomerate beds up to 30 cm thick contain pebbles of quartz, andesite, quartzite and granite. Other units of the Watheroo section are not well preserved in outcrop. They consist chiefly of red-brown shales with subordinate silicified limestones and arkose intercalations.

Petrography.—The siltstones of the formation can be divided into three end-member types on a basis of mineralogical content. These are: (1) arkosic siltstone, (2) calcareous siltstone and (3) tuffaceous siltstone. However these subdivisions are not distinct and there is considerable intergradation between end members.

Arkosic siltstones: The siltstones of the arkosic suite of sedimentary rocks have quartz, feldspar and mica as the principal silt-size detrital constituents. The rock type is usually brown or brown-red in colour, except adjacent to dolerite intrusions where the development of secondary chlorite imparts a gray-green colour to the rock. The structure varies from massive to fissile; the parting along bedding planes from good to poor. Jointing is generally smooth and regular. The arkosic siltstones contain small-scale sedimentary structures such as ripple marks (1.5 mm wavelength), graded-bedding, cross-bedding (5 cm thick), mud-ball conglomerates (1.5 mm in diameter) and small slump structures. In thin section siltsize detrital grains of feldspar, muscovite and biotite are observed in a matrix of the same minerals as well as sericite, chlorite, hematite, magnetite and clay minerals. A siliceous cement is commonly developed. Weathering processes, particularly lateritisation, effect colour changes due to concentration, alteration or removal of iron oxides and the kaolinisation of the feldspars.



Fig. 3.—Ripple-marked slab of tuffaceous and calcareous siltstone from unit 11 of the Dalaroo Siltstone at Watheroo, Western Australia.

Calcareous siltstone: Siltstones containing detrital carbonate occur in the topmost unit of the Watheroo section and in the basal units of the Coomberdale section. The occurrence of clastic carbonate with pyroclastics at Watheroo has been described above. Beds and lenses of pink, rounded carbonate particles (up to 2 mm) occur in a shaley deep-red siltstone matrix. As seen in thin section the detrital carbonate is intermixed with detrital quartz, feldspar and microcrystalline volcanic rock fragments; the matrix is dense and composed of sericite, chlorite and iron-stained material. Partial replacement of the carbonate by chlorite is indicated in some sections. The calcareous unit at Coomberdale is red-purple, massive with widely-spaced joint planes and uneven fracture. The carbonate occurs as rhomb-shaped grains with microcline and quartz in a matrix of fine silt and iron-stained clay. Weathered surfaces of the calcareous siltstones resemble vesicular basalt due to solution of the carbonate grains which leave cavities in the matrix.

Tuffaceous siltstone: The tuffaceous siltstones in the formation typically contain detrital fragments of vesicular volcanic glass and/or microcrystalline igneous rocks of andesitic composition and detrital feldspars. Detrital quartz is not abundant. The matrix is composed of finely disseminated hematite with sericite and chlorite. Diagenesis has resulted in devitrification of glassy matter, potash enrichment of feldspars and development of secondary chlorite and epidote. The pyroclastic tuff at Coomberdale is interbedded with epiclastic tuffaceous siltstones. It is a gray, massive rock, poorly bedded containing angular blocks of red-purple siltstone. Volcanic glass fragments which constitute approximately 60% of the rock are often bent or warped around each other denoting a plastic state at deposition. The glass shards contain small inclusions of iron-ore, feldspar and quartz as well as clay aggregates. Small xenoblasts of epidote occur throughout the rock.

A number of arkosic sandstone units or members are developed in the Dalaroo Siltstone. Arkosic sandstones occurring low in the sequence resemble similar rocks in the Capalcarra Sandstone while those developed higher in the sequence are similar to the arkoses of the overlying Mokadine Formation. Microcline is the dominant feldspar.

A thin chert unit occurs interbedded in the type section of the Dalaroo Siltstone. The chert is highly weathered with a saccharoidal appearance and a faint stromatolitic banding. The Watheroo section also contains a few chert units. There is evidence here for a replacement origin for the chert as there are remnants of calcarenite and laminated algal limestone breccias.

The Mokadine Formation

The Mokadine Formation is a sequence of siltstone and claystone, well-sorted arkose and feldspathic sandstone and minor chert which conformably overlies the Dalaroo Siltstone and is overlain by the Coomberdale Chert. The name is taken from Mokadine Spring, a small soak

1½ miles east-north-east of Moora (the highland surrounding the spring where the type section of the formation is exposed is known locally as Mokadine Hill). The formation was originally named "Mokadine Arkose" (McWhae *et al.* 1958) because of the prominence of arkose units in the field and the prevalence through the formation of clastic sediments containing microcline and quartz. However, true arkose units make up only a small part of the total thickness in the type section. Therefore, to comply with the Australian Code of Stratigraphic Nomenclature of 1956, the name is amended to Mokadine Formation.

The type section near Mokadine Spring (30° 38' S; 116° 02' E) is as follows:

Noondine Member, Coomberdale Chert

Orthoquartzite and silicified limestone containing the Coomberdale problematic fossils. Conformably overlies the Mokadine Formation.

Mokadine Formation

| | Thickness (Feet) |
|--|--------------------------------|
| 11. Gray and grayish-purple siltstone. Crops out as blocks and cobbles in soil. Flaggy to shaly, with alternate purple and gray indistinctly separated laminae. Dense, non-friable with smooth break along joints and bedding planes. Gray laminae are 50% microcrystalline quartz cement and 46% detrital microcline and quartz with iron-ore and epidote as minor constituents. Purple laminae, in addition to the above constituents, contain abundant microcrystalline grains of hematite. Spec. 36818 | 10-20 |
| 10. Grayish red massive silty claystone. Weathered joint blocks litter uncleared area. Contains mud balls. Silt-sized components are kaolinised feldspar and rare shreds of sericite and chlorite in a matrix of iron-stained clay. Spec. 36817 | 55 (with underlying member) |
| 9. Pale red-purple conglomeratic feldspathic sandstone, white and orange on exposed surfaces. The pebbles in the conglomerate are chert. The remainder is made up of rounded quartz grains with sericite inclusions (49%), kaolinised feldspar grains (9%), rounded detrital chert grains and rare muscovite flakes (1%) and a microcrystalline quartz cement with carbonate inclusions (37%). Spec. 36816. | |
| 8. Banded chert, white to gray. Exposure of angular joint blocks | 10 |
| 7. Grayish-red shaly calcareous siltstone. In thin section it is made up of laminae about 5 mm thick, each grading from coarse siltstone at the base to thin sub-laminae of fine siltstone at the top. The detrital constituents are carbonate (up to 25%), plagioclase, potash feldspar, muscovite and quartz in varying proportions in a matrix (50-90%) of iron-stained clay, sericite and chlorite | 105 |
| 6. Arkose, exposed <i>in situ</i> . Progressively lighter in colour from bottom to top, grayish-red to light brown. Shaly at the base, massive at the top. The roundness of quartz grains increases upwards. Detrital constituents are sub-angular to rounded quartz (50-60%), surrounded by authigenic overgrowths, well-rounded feldspar, chiefly microcline (35-50%) and muscovite and magnetite (3-5%). The cement (10-15%) is siliceous and contains hematite inclusions. Spec. 36813, 36814 | 50 |

5. Tuffaceous siltstone exposed *in situ*. Grayish-red to blackish-red. Made up of laminae of claystone and siltstone with occasional layers of sandy siltstone. Fracture, semiconchoidal; hardness, even. Silt and sand-sized grains of feldspar and devitrified glass in varying proportions lie in an iron-stained clay matrix. Grains of optically positive plagioclase form stout lath-shaped euhedra sometimes rimmed with devitrified glass. Grains composed wholly of the latter are also present. The devitrified glass is rich in potash feldspar, anhedral of chlorite and crystals of magnetite. The latter mineral also occurs as rounded grains. Quartz replaces parts of some plagioclase laths. Spec. 36812 ... 28
 4. Feldspathic sandstone, exposed *in situ*. Dark orange-yellow to light gray. Flaggy to massive. Silicified, hard and non-friable. Medium-grained, well-sorted. Constituents are well-rounded heavily overgrown quartz (85%), rounded saussuritised microcline (13%) and iron-ore and chert grains (2%) ... 36
 3. Arkose, cropping out as angular boulders. Fine-grained with medium-grained layers. Light brown, flaggy and friable. Constituents are well-rounded grains of quartz, with sutured overgrowths on the grains and well-rounded grains of microcrystalline chert (50%), saussuritised and kaolinised feldspar, chiefly microcline, with rare andesine (35-50%), iron-ore, rare colourless non-pleochroic zircons and very rare purple tourmaline (1%), and the remainder siliceous cement. Spec. 36810 ... 13
 2. Fine-grained arkose, exposed *in situ*. Grayish red-purple. Shaly, with alternating finer and coarser laminae up to 5 mm thick. Non-friable. In thin section, grains show an average roundness of 0.2 with a correspondingly low sphericity. Quartz (39%) is overgrown with siliceous cement (11%) which contains abundant red highly refringent inclusions of hematite. Feldspar (26%) mainly microcline with some oligoclase. Iron oxide is present as detrital magnetite and secondary hematite. Spec. 36809 ... 11
 1. Medium-grained arkose, cropping out as a low cliff with talus at the base. Cross-bedded. Non-friable, weathers to a light brown, but when fresh, pale red. Grains well-rounded, 64% quartz, with undulose extinction and authigenic overgrowths, 28% microcline. Small amount of detrital chert, iron-ore and colourless zircon. Cement is microcrystalline quartz. Spec. 36808 ... 16
- Total thickness of Mokadine Formation 330 feet.

Dalaroo Siltstone

Tuffaceous sandy siltstone.
Spec. 36784, 36785.

The Mokadine Formation outcrops in the Moora-Coomberdale area but it is absent from the Moora Group section at Watheroo where the Coomberdale Chert immediately overlies the Dalaroo Siltstone with apparent conformity. The maximum measured thickness is the 330 feet of the type section at Mokadine Hill, Moora. The formation outcrops again at Coomberdale where a monotonous succession, 300 feet thick, of arkose and feldspathic sandstone occurs overlying tuffaceous upper units of the Dalaroo Siltstone. The Mokadine Formation has not been recognised north of Coomberdale but since the outcrop between Coomberdale and Watheroo was not mapped in detail there is a possibility that exposures may exist in this area.

Petrography.—The Mokadine Formation is composed of two dominant lithological suites, arkose and feldspathic sandstone and arkosic siltstone. There are also minor intercalations of silicified limestone (now chert).

Arkose and feldspathic sandstones comprise 60% of the type section at Moora and almost 100% of the Coomberdale exposures of the formation. The feldspathic sandstone suite are orange to pink, well-sorted arenites with 10 to 25% microcline feldspar, approximately 70% detrital quartz, 5% microcrystalline or sutured quartz aggregates and magnetite (up to 5%). The individual grains are sub-rounded to rounded and feldspar is usually more highly rounded than quartz. Detrital quartz grains commonly have authigenic quartz overgrowth. The cement is siliceous. Secondary sericite and epidote are occasionally developed.

Arkosic siltstones and rare tuffaceous siltstones comprise 34% of the type section at Mokadine Hill and also outcrop in the Moora area to the north of the Moore River. The arkosic siltstones are grayish red to brownish red rocks composed chiefly of silt-size detrital feldspar with lesser amounts of detrital quartz, detrital carbonate and in some members volcanic glass. The matrix consists chiefly of iron-stained clay, sericite and chlorite.

The Coomberdale Chert

The name Coomberdale Chert is applied to the sequence of bedded cherts, chert breccias, orthoquartzites and silicified limestones overlying the Mokadine Formation in the type section at Coomberdale and the Dalaroo Siltstone at Watheroo. The upper boundary of the Coomberdale Chert has not been observed. The formation is named after Coomberdale, a small railway siding on the Perth to Geraldton line, 130 miles north of Perth. The type section which is exposed in a series of fault blocks in the area south of Coomberdale (latitude 30° 28' S; longitude 116° 02' E) is detailed as follows:

Erosion Surface Coomberdale Chert

| | Thickness (Feet) |
|---|---------------------|
| 22. Chert, intraformational slump breccias and folds are common features. Stromatolite structures are present; exposure varies from cliff to bouldery outcrop | 1,100 + |
| 21. Koolera quartz sandstone member; fine to medium-grained orthoquartzites with secondary overgrowth on the detrital quartz to complete cementation. Chert breccias and conglomerates ranging from cobble to granule size are prominent especially at the base. Rare beds of massive, brown siltstone are present. Sedimentary structures are current ripple marks, mud cracks, intraformational mud curls and clay galls. Outcrop is bouldery | 160 |
| 20. Chert, intraformational slump breccias and stromatolites. The strongly jointed chert varies from cliff to bouldery outcrop | 480 |
| 19. Kiaka quartz sandstone member, fine to medium-grained orthoquartzites with chert breccias at the base and with lenses of bedded chert which are partly stromatolitic. The orthoquartzites are red, brown and white in colour and commonly massively bedded. Current ripples are common | 380 |

| | | |
|-----|---|-------|
| 18. | Chert as for unit 21 | 550+ |
| 17. | Orthoquartzite with 40% chert cement, white, fine-grained. The unit is dominantly composed of silicified tubes of a problematic fossil which may be an alga, stromatoporoid or coral. Rare small algal colonies of <i>Collenia columnaris</i> Fenton and Fenton are present | 65 |
| 16. | Orthoquartzite, medium-grained with a chert cement, cross-bedded | 80 |
| 15. | Orthoquartzite, white, medium to coarse-grained, massively bedded | 71 |
| 14. | Orthoquartzite, mottled brown and white, strongly current-bedded. Chert cement 1 to 5%. Sorting poor, approximate average grain size 0.6 mm | 10 |
| 13. | No outcrop unit, obscured by sand cover | 10 |
| 12. | Chert, white opaque massive | 15 |
| 11. | Orthoquartzite, white, medium-grained, massively bedded, chert cement | 35 |
| 10. | Chert, white, thinly bedded with detrital quartz grains in thin laminae. Detrital grains 0.1 mm diameter. A palimpsest oolitic texture is visible in the chert | 40 |
| 9. | Orthoquartzite, pink fine to medium-grained, with well-developed current-bedding. A chert cement is present (40%). Rare chert fragments are also visible in thin section | 86 |
| 8. | Orthoquartzite, light gray, fine-grained, cross-bedded, clay cement | 1 |
| 7. | Orthoquartzite, pink, fine to medium-grained with well-developed current-bedding, roundness of grains low, size sorting poor. The cement is a clay of micaceous habit | 5 |
| 6. | Orthoquartzite, white, medium-grained, well-sorted, 6" x 12" lenses of pink orthoquartzite are present. Silicified problematica colonies occur at the base. Chert occurs as a cement and in thin beds (10 to 40 mm) and irregular lenses throughout the unit | 30 |
| 5. | Unit obscured by sand cover | 87 |
| 4. | Orthoquartzite, white, coarse-grained, well-sorted, approximate average grain size 1 to 1.5 mm, massively bedded | 3 |
| 3. | Orthoquartzite, white, medium-grained, massively bedded with silicified problematica colonies in a biostromal development. Five cm beds of white and pink chert are also present | 40 |
| 2. | Orthoquartzite, white, medium-grained, well-sorted, massively bedded | 20 |
| 1. | Orthoquartzite red to white, fine to medium-grained, strongly current-bedded. Rare current ripples of 40 mm wave length and 17 mm amplitude are present. Thin section discloses a chert cement and silicified oolites | 35 |
| | Total thickness of Coomberdale Chert | 3,303 |

Mokadine Formation

The Coomberdale Chert outcrops in a two-mile wide belt between Moora and Coorow. The western outcrop boundary forms the front of the Darling Scarp. In the Moora-Coomberdale area the formation overlies the Mokadine Formation with apparent conformity. At Watheroo this arkose is not represented in the section and the Coomberdale Chert rests directly on the Dalaroo Siltstone.

The Watheroo section of the formation is characterised by thick members composed of elastic breccias. North of Watheroo outcrops are mainly obscured by sand plain cover; at Gunyidi scattered solid outcrop of chert and intraformational (slump) breccias project above the sand cover. Fairbridge (1950) recorded *Collenia* from the Coomberdale Chert in this

area. In the vicinity of Coorow a few scattered outcrops of chert are found in the sand plain and at Coorow Cave, 5½ miles south-west of Coorow townsite, a silicified dolomitic limestone containing stromatolites is exposed in the walls of the cave. The limestone is overlain by sandstones bearing ripple marks and cross-bedding. A two directional system of vertical joints filled with quartz stand out on the weathered surface as box work structures.

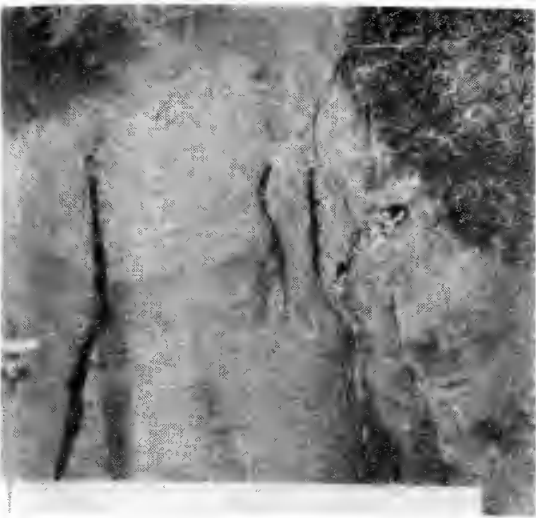
Like other formations in the Moora Group the Coomberdale Chert was not traced in outcrop north of Coorow. J. A. Lalor and P. A. Arriens of the Department of Geology, University of Western Australia, report lithologically similar cherts in the Billeranga Hills area which may be part of a northerly extension of the formation but at the time of writing no continuity has been traced between Coorow and the Billeranga Hills.

Chert

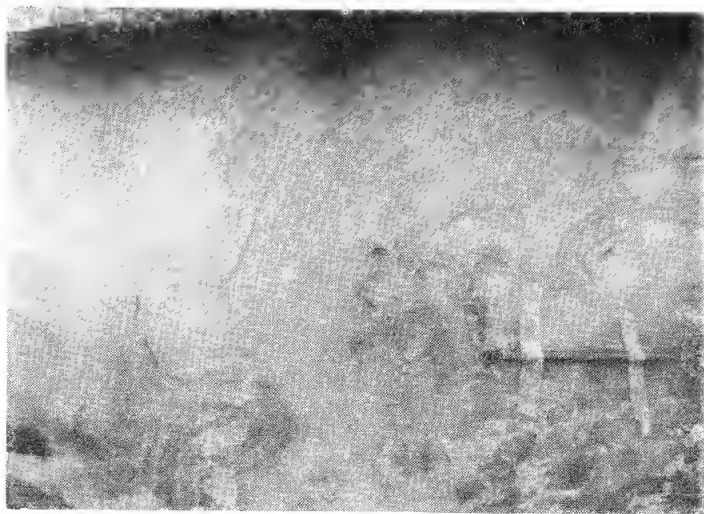
Chert forms a series of thick strongly jointed members in the formation. They are strongly banded rocks with light gray, dark gray and pink laminae; much of the lamination has a micro-undulation of a few cms amplitude which is stromatolitic in nature. The chert is a novaculite type composed predominantly of micro-crystalline quartz with a mosaic texture of interlocking polyhedral quartz crystals, 0.01 to 0.02 mm crystal size. According to Folk and Weaver (1952) such a texture results from crystallisation about closely spaced centres distributed in a three-dimensional plan. Chalcedonic quartz is very rare and only occurs in spherulites and bands around "agate" or colloform textures.

Minute, equidimensional carbonate inclusions, probably calcite are almost universally distributed throughout the chert members. The inclusions are relicts of the original carbonate sediments which have been silica metasomatised to form chert. The criteria for such a replacement are outlined and briefly discussed elsewhere in this paper. Dolomite rhombs occur in many of the chert beds and sometimes these are replaced by quartz to form dolocasts—rhombic quartz crystals pseudomorphous after dolomite.

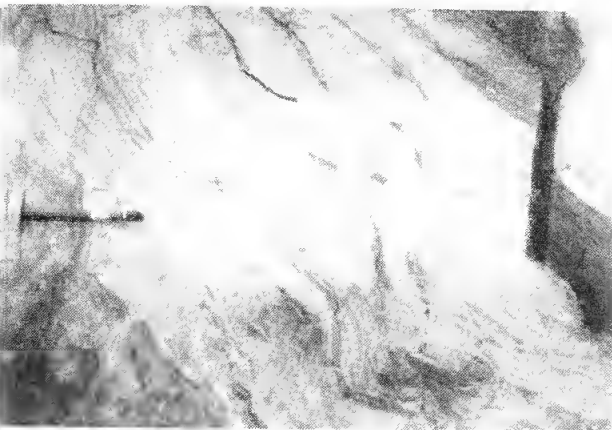
Intraformational folding and brecciation.—Symmetrical and asymmetrical folds, minor overfolds and miniature nappes are beautifully exposed in cliff sections of the bedded cherts. This contortion is strictly intraformational and the folds grade upwards or downwards into zones of intraformational chert breccia. The amplitude of the contortion varies from one to several feet, but the impression is that these are merely smaller folds on the flanks of larger intraformational undulations. The smaller synclines are broadly convex, the anticlines more often sharply constricted at the crest (Plate I, Fig. 1) suggesting folding or slumping under minimal load. Intraformational overfolding and subsequent breakage of the overfold has produced miniature nappes which have been thrust forward over flat-lying undisturbed beds; nappe formation is uncommon due most likely to the general competency of some laminae which fail by fracture to produce breccias. One



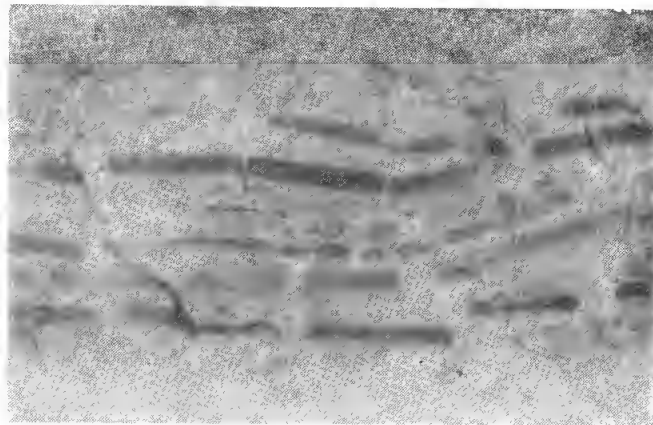
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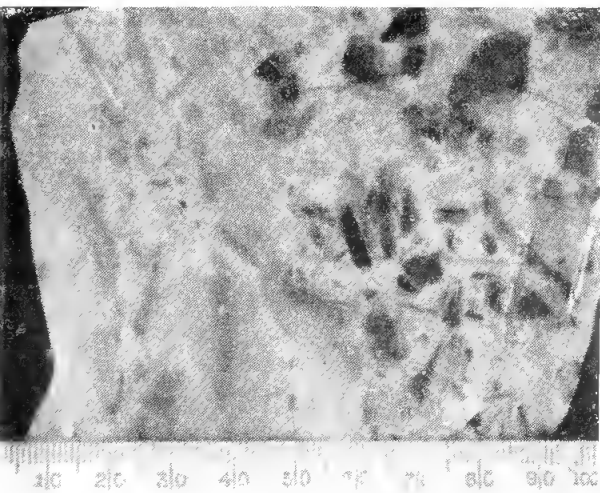
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3



4



5



6

PLATE I

- Fig. 1.—Intraformational slump folding exposed on a vertical joint face in the Coomberdale Chert at Kiaka Cliff, Coomberdale. Broadly convex syncline and sharply folded anticline grade down into almost undisturbed laminae. Scale is a one foot rule.
- Fig. 2.—Intraformational contortion with incipient brecciation of thin, dark gray laminae in chert at Kiaka Cliff, Coomberdale.
- Fig. 3.—Intraformational chert breccia and folding in the Coomberdale Chert at Kiaka Cliff, Coomberdale. The breccia fragments are not disturbed from the original bedding positions.
- Fig. 4.—Intraformational chert breccia in which the fragments are little disturbed from the original bedding directions. The fragments are approximately 20 to 30 mm in length.
- Fig. 5.—Intraformational chert breccia from the Coomberdale Chert at Kiaka Cliff, Coomberdale. No trace of original bedding is preserved in this specimen. Compare with Figures 3 and 4 above.
- Fig. 6.—Cross-section of a "snowball" or spiral slump in chert from the Coomberdale Chert, Coomberdale. The spirally arranged laminae have been brecciated and flattened on the under surface, presumably where the slump came to rest.

"snowball" or spiral slump (Plate I, Fig. 6) was observed in the chert outcrop at Kiaka Cliff. The spiral slump has a diameter of 250 mm and is composed of spirally arranged brecciated laminae flattened on one side; the side on which the snowball came to rest. Fairbridge (1942) discusses snowball or spiral slumps as features due to rotary movement of sediment down slopes and the gathering of sediment into the rolling mass.

Continuity of the chert bedding can be traced laterally for only short distances before the bedding is disrupted and passes into zones of intraformational chert breccia. The bedding may be totally or partially disrupted (Plate I, Figs. 2, 3, 5). The breccia fragments are light gray to dark gray in colour and angularly tabular in shape. Their elongation is parallel to the original bedding (Plate I, Figs. 3, 4) and their length ranges from 3 mm to 100 mm with an average length around 25 mm; the thickness of the fragments is dependent on the thickness of the original bedding or laminae from which the fragments were derived, averaging about 10 mm. The cement or matrix is a white chert.

Brecciation is clearly due to the intraformational stresses which caused the contortion and all gradations exist between partially brecciated beds in which the laminae are contorted and broken but undisturbed from their bedding positions (Plate I, Figs. 2, 3, 4) and chert breccias in which no trace of the original bedding is preserved (Plate I, Fig. 5). The final phase in the intraformational breakup is the plastic injection of intraformational breccia as sills and dykes into adjacent beds. These structures are similar to clastic dykes in sedimentary strata which according to Fairbridge (1942) are features of regions with penecontemporaneous slumping.

While intensity of movement must be the chief factor in determining the nature and extent of folding and brecciation within the formation, the lithology (or more correctly the physical state) can be shown to have a marked influence. Hence intense contortion and intraformational brecciation occurs in the members where thick, white laminae (20 to 30 mm) predominate over thin (5 mm) gray laminae. At other localities where the gray laminae are dominant in the section, the bedding is only slightly disturbed or thrown into folds without brecciation. It is deduced that beds and laminae now represented by white chert behaved in a plastic manner and failed by flowage under stress. On the other hand the laminae now represented by gray chert reacted competently and failed by fracturing to form the breccia fragments.

Gravity sliding is a likely mechanism for this form of intraformational disturbance and two conditions are prerequisite: one, an unconsolidated state of the sliding mass and two, an inclination of the substratum on which the sediments can slide. Brecciation requires the presence of lithified laminae interbedded in the moving sediment mass. The relationship of folding to brecciation indicates that the pre-fold sediments were a complex of lithified but fragile beds and laminae alternating with unlithified

incompetent beds. With this condition and under stresses set up in the sliding sediment mass, beds of incompetent nature flowed and contorted readily while interbedded competent beds fractured into breccia fragments.

Lees (1928) ascribed intraformational folding and brecciation in the Campanian cherts of Palestine, Syria and Jordan to internal forces of expansion of precipitated silica gel which shattered the interbedded limestone (and apparently chert) into fragments. However, Fairbridge (1942) considered this intraformational folding was due to penecontemporaneous subaqueous slumping and related the brecciation to the same process. The questions of intraformational slumping and chert origin have been linked since the presence of slump features have led to the assumption of a colloidal silica gel state for the original rock and hence a distinct prejudice against a metasomatic origin for the cherts containing them, Lees (1928), Fairbridge (1942) and James (1954). That cherts are necessarily syngenetic if they contain slump features is not a completely sound argument for slumping implies only a certain set of physical conditions which may be unrelated to chemical composition.

Origin of Chert

The controversial topic of chert origin whether syngenetic or epigenetic, has been debated in the geological literature for many years. It is not our intention to discuss the matter in this paper as we feel it has been adequately covered by numerous authors. The Coomberdale Chert is considered by the writers to be due to the silica metasomatism of an original carbonate rock formation; a post-consolidation replacement which has preserved most of the original sedimentary structures and textures of the metasome. This conclusion has been reached after careful evaluation of all the criteria for chert origin present in the field and in thin section. The criteria observed in the Coomberdale Chert are overwhelmingly in favour of replacement origin of chert. These observations are listed, discussed and evaluated below:

(a) *Gradation of chert rock types into similar carbonate rock types in outcrop.*—The strongest argument for replacement origin can be seen in the walls of Jingemba cave, Watheroo, where there is a gradation from chert breccias (with orthoquartzite matrix and microcrystalline quartz cement) into dolomitic limestone breccias (with orthoquartzite matrix and carbonate cement). In this locality chert breccias on the surface grade down into the carbonate rocks with similar textures and structures at depths of 30 to 40 feet. Selective replacement is indicated in thin sections from this exposure for the coarse, crystalline calcite of the cement is replaced in the earliest stages of metasomatism while the dense cryptocrystalline carbonate of the fragments is unaffected. With progressive increase in SiO_2 the fragments are replaced by microcrystalline quartz which even in the final stages of chertification is replaced with minute relict inclusions of carbonate.

(b) *Silicification of carbonate fossils.*—Chertified stromatolites are abundant in the bedded cherts and also occur as fragments in the clastic chert breccias of the Watheroo section. This evidence speaks for itself.

(c) *Silicification of oolites.*—Silicified oolites and oolitic textures present in the Noonidine member point to a replacement process where the original carbonate oolites have been replaced by silica. This criterion for replacement was first advanced by Van Tuyl (1918) and most workers agree that it is valid. One exception has been a paper by Krynine *et al.* (1941) which describes primary siliceous oolites interbedded with carbonate oolites in the Upper Cambrian of central Pennsylvania;

however, Choquette (1955) refutes the hypothesis of Kryniene *et al.* (1941) and believes that this oolite also owes its character to the silicification of an original carbonate oolite.

(d) *Relict carbonate inclusions in chert.*—Minute, relict inclusions of carbonate, probably calcite, are almost universally distributed in the chert of the formation; they are particularly abundant in laminae in which the microcrystalline quartz is approximately 0.2 mm diameter and apparently physico-chemical conditions in these laminae were more suitable for the preservation of the inclusions after silicification. There is little doubt that these inclusions are relict as their formation has been observed along the carbonate-microcrystalline quartz interface in partially replaced dolomitic limestones. Dolomite rhombs which occur occasionally in the chert are also to be regarded as relict after replacement; in some instances the dolomite rhombs themselves may be replaced by quartz with the formation of quartz dolocasts after dolomite. Perhaps the best criterion for selective replacement is seen in the dolomitic limestones in which the rhombs are zoned and contain calcite cores. In many instances the calcite has been selectively replaced, resulting in rhombs with a core of microcrystalline quartz rimmed with dolomite.

(e) *Widespread quartz overgrowth in the clastic members of the formation.*—Most of the orthoquartzites in the Coomberdale Chert have secondary enlargement of quartz in optical continuity with the detrital quartz grains. Widespread quartz overgrowth is not direct evidence for a replacement origin of the chert; what is indicated is that large amounts of silica circulated throughout the sequence. Chert cements and chert fragments in the orthoquartzite members can reasonably be regarded as products of SiO_2 metasomatism of original carbonate cements and fragments, particularly in view of the occurrence of silicified fossil fragments and silicified oolites in the detrital fraction. This argument is further strengthened by the findings of Folk and Weaver (1952) who point out that silica deposited in intergranular spaces would be in the form of chalcedony whereas microcrystalline quartz is commonly formed by replacement of carbonate.

The present writers consider that the chert fragments and microcrystalline cements in many of the orthoquartzites of the formation were produced by silica solutions replacing the original carbonate fragments and cements; the same solutions produced secondary overgrowth on the detrital quartz grains.

(f) *Mineralisation of joints and fissures by quartz.*—At Coorow Cave vertical joints in the limestones contain normal quartz as joint fillings, and these are contiguous with siliceous laminae (chert) interbedded with the dolomitic limestones of the cave walls. The veins and siliceous laminae are more resistant than the surrounding dolomitic limestones and they stand out on the weathered surface as box-work structures. The presence of these joint fillings at Coorow and elsewhere in the chert not only indicates replacement as a process but also that replacement was a post-lithification feature and did not occur when the sediments were unlithified on the sea floor.

(g) *Transgression of bedding by irregular chert masses.*—Transgression of bedding by irregular chert masses was advanced as a criterion for replacement by Van Tuyl (1918); such transgression is observed at a number of locations in the Coomberdale Chert.

Clastic Orthoquartzite Members

Clastic members comprise about 40% of the Coomberdale Chert formation and the main features of the three clastic units occurring in the type section are described herein as typical of other clastic members in the formation.

The Noondine Member.—The basal 640 feet of interbedded orthoquartzites and chert in the type section at Coomberdale is a mappable unit termed the Noondine Member.

Sand size clastics predominate in this unit with a grain size range from coarse to very fine in the Wentworth scale of grade; sorting is generally good and the detrital quartz grains are usually well rounded. Secondary enlargement by quartz overgrowth of the quartz grains

is very common and in this case the original outlines of the grains are delineated by lines of minute indeterminate inclusions. Most of the orthoquartzites contain chert as a cement (microcrystalline quartz) and there are all lithological variations from pure orthoquartzites to orthoquartzites with chert cements to cherts with detrital quartz to pure cherts.

Current bedding and ripple marking is widespread and testifies to a shallow water environment of deposition. In these conditions a thriving biostromal growth of a tubular colonial organism of unknown affinities (possibly an alga or stromatoporoid) developed in three distinct horizons within the member. All the organic remains are completely silicified. In the uppermost horizon (unit 17 of the type section) the problematica is associated with the stromatolite *Collenia columnaris* Fenton and Fenton in a lithology of very fine-grained orthoquartzite and chert. The stromatolite growth fabric and occurrence gives clear evidence of ecological conditions in the biotope. The algal colonies average 5 mm in cross-section and stand 5 to 20 mm in height. The heads taper towards the base. In general the inter-colony spaces are filled with a fine-grained orthoquartzite in which the detrital quartz grains are approximately 0.12 mm grain size. Two per cent. of the detrital fraction is detrital chert of 0.8 mm average fragment size. There is a high concentration of "heavies," chiefly magnetite and zircon, occurring as a placer deposit in the inter-colony spaces which indicates sediment entrapment under turbulent water conditions. An ecological reconstruction of the environment is given in Table I.

Orthoquartzites with silicified calcareous oolites and cherts with palimpsest oolitic texture throughout the member also indicate deposition in shallow, agitated waters as well as being in themselves first class evidence for the silica replacement of original carbonate rocks which contained them.

The sequence of rock types has an overall shallow neritic to littoral aspect; all the characteristics of these zones as summarised by Kuenen (1950), abundant algae, limestones, oolites and fine to coarse clastics with current-bedding and ripple marks are present.

TABLE I

Ecological Analysis of the Problematic Fossil Biotope—Unit 17

Factors Pertaining to the Substratum

- (a) Composition of the substratum:
Fragmental, fine- to medium-grained sand admixed with carbonate mud and particles. Heavy minerals, zircon, magnetite.
- (b) Inclination of the substratum:
Unknown.

Factors Operative on the Substratum

- (a) Movement of sediment on the substratum:
Individual movement, sorting and concentration of the heavy mineral detrital fraction between algal colonies.
- (b) Character and activity of benthonic life:
Dense population of sessile colonial organisms. Tight packing of the problematica tubes. Small stromatolites grow in more open positions.

Factors Pertaining to the Medium

- (a) Motion of the medium over the bottom:
Turbulence and directive currents, variable. Excellent size sorting and heavy mineral "placering" in the detrital fraction indicates small range of current velocity with intermittent strong current action and turbulence.
- (b) Chemical precipitation:
Periods of calm allow for the organic precipitation of calcium carbonate.

Factors Above the Substratum

- (a) Dissolved gas content:
Oxygenation probably normal as evinced by agitation and prolific growth.
- (b) Salinity:
Unknown; density of life indicates a large turnover in calcium salts.
- (c) Temperature:
Unknown.
- (d) Character of the suspensoid load:
Fine sand, mostly quartz, carbonate silt and heavy minerals moved intermittently during times of stronger currents and turbulence. Low turbidity. Larger particles moved in times of strong current action and the finer particles are then in suspension.
- (e) Light intensity:
Strong to moderate to meet the photosynthesis requirements of the stromatolite algae.
- (f) Depth:
Less than 30 metres.

Kiaka Sandstone Member.—The 380 feet of medium-grained orthoquartzites, cherts and chert breccias termed the Kiaka Member form a mappable unit in the southern outcrop of the formation around Moora. The orthoquartzites are current rippled and thickly bedded; the characteristic lithology of the member is an orthoquartzite with chert fragments. It is a reddish brown, medium-grained, massively bedded rock with 60% detrital quartz grains which are well-rounded and sorted. Approximate average grain diameter is 0.3 mm. Some of the detrital quartz grains are sutured indicating a source in the Archean massif to the east. In character the Kiaka Member is a shallow water deposit of littoral or neritic aspect.

Koolera Sandstone Member.—Lithology of the Koolera Member is dominantly quartz arenites, but a few silty sandstones and siltstone units are interbedded. Clastic chert breccias and conglomerates with orthoquartzite matrix appear at the base of the member. The orthoquartzites range from fine to coarse on the Wentworth scale of grade and the chert fragments from cobble to granule size. As in other clastic members of the formation the detrital quartz grains are often overgrown with quartz in optical continuity with the original grain. Fragments of chert and chert cements are uncommon and often contain minute relict inclusions of calcite.

Bedding is generally massive but asymmetrical current-ripples are present. Irregular mud cracks and mud curls point to desiccation by exposure to the atmosphere at some stages in the depositional history of the member. Limonitic mud balls and clay galls (now often chloritic) of 0.5 to 15 mm diameter are abundant in some of the outcrop.

Sedimentary structures, mud cracks formed by shrinkage of muddy sediments upon exposure of the wet muds to the desiccating influence of the

atmosphere and mud curls and mud balls which originate by penecontemporaneous erosion and deposition of thin lithified muddy layers (mud cracked layers) are indicative of intertidal shallow-water environments. In rolling about on an agitated sandy bottom the mud balls incorporate sand grains within themselves to form miniature "armoured" mud balls. Current ripples are also present. Reworking of the deposit has also left its imprint on the well-rounded and well-sorted nature of the detrital quartz fraction.

Clastic Chert Breccias and Conglomerates.—Chert breccias of clastic origin are developed in the Watheroo section of the formation. These breccias are distinct lithologically and genetically from the intraformational chert breccias of slump origin.

The clastic chert breccias are generally interbedded with orthoquartzites and normally have a detrital quartz sand matrix and microcrystalline quartz (chert) cement. The breccia fragments range from 0.5 mm to many metres across; the larger fragments are angular but rounding increases with decreasing size. The fragments of the stromatolites *Collenia columnaris* Fenton and Fenton and *Cryptozoon frequens* Walcott are a particularly striking if rare component of the fragmental fraction. The quartz matrix is generally medium-grained, well-sorted and the well-rounded nature of the grains is delineated by inclusions despite the overgrowth of authigenic quartz.

The unsilicified equivalent crops out in Jingemba Cave, Watheroo; here, the sandy chert breccias grade down into the unsilicified original rock type—a limestone breccia with sandstone matrix and carbonate cement.

The breccias of the Watheroo sections are true clastic breccias distinct from the breccias of intraformational slump origin. Limestone detritus has been derived from adjacent areas of limestone deposition and lithification such as algal bioherms and biostromes. The presence of broken fragments of the algal stromatolite morphotypes *Collenia columnaris* Fenton and Fenton and *Cryptozoon frequens* Walcott suggests the possibility that these are off-reef talus breccias. The large size of the fragments cannot be reconciled with normal sedimentary transport into lithotopes of sandstone deposition. The extreme variation in size of the fragments in a well-sorted sandy matrix means that this material was selected and deposited indiscriminately and this can be explained by the action of solifluction or turbidity currents; more probably by simple breaking off and movement of the blocks down the steep initial dips on the flanks of the reef structures.

Silicified Carbonate Rocks

In a few rare instances the original dolomitic limestones have escaped the silicification to which the terrain has been subjected. Caves at Coorow and Watheroo are due to solution of these rocks and one outcrop of the original limestone occurs at Moora at the southern extremity of the Coomberdale Chert outcrop. In all cases the limestones are stromatolitic and in them we see the beginnings of silicification.

Ice-borne erratics of the same lithology in the glacial Nangetty Formation (Sakmarian) of the Irwin River Basin have been derived from the Coomberdale Chert. Since these erratics are silicified and here are all stages of replacement from limestone to chert, the plucking of the boulders from their original position and their deposition in the Irwin Basin must post-date silicification, i.e. silicification occurred prior to the Sakmarian and not as Fairbridge (1950) suggests under conditions of deep continental weathering of the Palaeozoic, Mesozoic and part of the Tertiary.

Analyses of the limestones by the volumetric versenate method (Chung *et al.* 1952) to determine CaO/MgO ratio were carried out. SiO₂ and R₂O₃ can be readily estimated within this analytical procedure.

TABLE II

SiO₂, R₂O₃, CaO/MgO Ratio of Dolomitic Limestones from the Coomberdale Chert

| Sample No. | SiO ₂ | R ₂ O ₃ | CaO | MgO | CaO/MgO |
|----------------|-----------------------------|-------------------------------|-----------------------------|-----------------------------|---------|
| | ⁰ / ₀ | ⁰ / ₀ | ⁰ / ₀ | ⁰ / ₀ | |
| 36366 (a) | 6.04 | 1.15 | 26.78 | 19.32 | 1.38 |
| 36366 | 6.49 | 0.98 | 28.92 | 18.77 | 1.54 |
| 36367 | 7.60 | 0.09 | 27.87 | 19.44 | 1.43 |
| 36369 | 8.44 | 0.06 | 28.37 | 19.07 | 1.48 |
| 36368 | 42.58 | 0.02 | 18.89 | 10.77 | 1.76 |
| 36363 | 60.48 | 1.34 | 11.40 | 8.46 | 1.34 |
| 36397 | 66.2 | 2.00 | 9.73 | 6.29 | 1.54 |

All the carbonate rocks fall within the dolomitic limestone group of Pettijohn (1956) with high percentages of magnesium carbonate occurring mineralogically as the double carbonate of magnesium and calcium, the mineral dolomite. In the specimens analysed there is a progressive increase of silica from 6 to 66 per cent. and a pure chert is the end member of this silica replacement series.

The typical rock is a gray, crystalline, dolomitic limestone with a stromatolite banding of alternate light and dark gray bands of fine cryptocrystalline calcite (which stain heavily with silver chromate) and bands composed largely of dolomite porphyroblasts. Chert occurs as laminae (2-5 mm), discrete patches and labyrinthic intergrowths transecting the bedding, and it is usually full of small calcite inclusions and occasional "floated" dolomite rhombs. The concentration of dolomite rhombs at the chert-carbonate contact, possibly suggests that silicification was selective on calcite during the early stages of replacement.

Zoned dolomite rhombs contain calcite cores and the core may be selectively attacked so that a rhomboid rim of dolomite surrounds a central area of microcrystalline quartz. The dolomite-calcite zoning is also strong evidence for secondary enrichment in MgCO₃ (dolomitisation) which involves recrystallisation of the original limestone with the development of grano-blastic texture. A porphyroblastic texture of dolomite anhedral or euhedral in a matrix of calcite is but a stage towards the completion of the process. Dolomitisation tends to erase existing structures and textures, and if this process goes to completion only faint palimpsest structures are left.

Joint fillings and transgression of the limestone bedding by chert are pertinent to the

origin and demonstrate that silicification was a post-lithification feature and not a diagenetic process occurring in the soft sediments at or immediately below the depositional interface. Labyrinthic intergrowth is first class evidence of replacement which cannot be well explained by the other hypotheses of chert origin. The dolomitic limestones at Coorow Cave and Jingemia have a very extensive joint network which has been infilled with vein quartz and chert; beds of chert in the limestone can be traced directly from the joints.

Palaeontology of the Moora Group

The Moora Group is characterised by an abundance of stromatolitic structures many of which are undoubtedly algal in origin. Most of the fossils are located in the Coomberdale Chert and are heavily silicified. Clarke *et al.* (1951) recognised stromatolite rocks in "... various stages in the replacement of the original limestone by silica" as erratics in the glacial Nangetty Formation which outcrops in the Irwin River Basin. The realisation that the erratics were derived from the Moora Group (then Yandanooka Group) to the south of the Irwin led to the discovery of algal structures in the Coomberdale Chert at Gunyidi and Moora (Fairbridge 1950). During the work for this paper the present writers have uncovered many more occurrences in the Coomberdale Chert including small biohermal developments.

Stromatolites and stromatolitic sediments are known from rocks of all ages ranging from Pre-cambrian to Recent. Walcott (1914) and Fenton and Fenton (1931, 1933, 1937) have recorded them in biostromal and biohermal developments in the Beltian of North America. In Australia stromatolites have been recorded in the Adelaidean by Mawson and others, and from the Proterozoic rocks of the Northern Territory by Traves (1954). Their occurrence in Recent carbonate sediments in the Bahamas and Florida has been noted by Black (1933), Ginsburg (1955) and Ginsburg and Lowenstam (1958). The form-genera and form-species have little chronological value except perhaps in local correlation (Rezak 1957), but Cloud (1942) and Rezak (1957) have both pointed out the palaeoecological significance of the forms. Rezak in particular has drawn valuable analogies from Recent occurrences in interpreting palaeoecology and palaeogeography in the Beltian.

The writers agree with Cloud (1942) that a rigid application of the Binomial Nomenclature to stromatolite forms which are a response to ecological factors rather than specific differences is not strictly valid. However, there seems to be a general agreement among workers that some systematic nomenclature should be applied.

A binomial nomenclature is applied to the stromatolites occurring in the Moora Group, but it is realised that the forms are probably due to the activities of a number of algae and that form is probably a result of interaction of algae with physical factors in the environments. Naming is based only on external form as the only microstructure evident is a crude lamination transverse and upwardly convex.



1



2



3



4

PLATE II

- Fig. 1. Stromatolite morphotype *Collenia undosa* Walcott in chert from the Coomberdale Chert at Gunyidi, W.A. Note the interruption to the regularity of the laminae at the top of the specimen. Longitudinal section.
- Fig. 2. Stromatolite morphotype *Collenia columnaris* Fenton and Fenton, longitudinal section exposed in a silicified, dolomitic limestone erratic in the Nangetty Formation, Beckett's Gully, Irwin River.
- Fig. 3. Stromatolite morphotype *Cryptozoon frequens* Walcott from a small bioherm in the Coomberdale Chert at Coomberdale. The original limestone has been replaced by chert. Note the flat axial plate in the centre of the colony.
- Fig. 4.- Silicified problematica colonies, underside view showing tubes radiating from a central holdfast. Note the orthoquartzite substratum on the right of the specimen. From unit 17 of the Coomberdale Chert type section at Coomberdale.

Collenia undosa Walcott

Plate II, Fig. 1

Walcott, C. D., 1914, *Smithson Misc. Coll.* 64, p. 113, pl. 13, Figs. 1-2; pl. 14, Figs. 1-2.

Fenton, C. L., and Fenton, M. A., 1931, Algae and algal beds in the Belt Series of Glacier National Park. *J. Geol.* 39, p. 684, pl. VI and pl. VII, Figs. 3-5.

Fenton, C. L., and Fenton, M. A., 1937, Belt Series of the north: stratigraphy, sedimentation, palaeontology. *Bull. Geol. Soc. Amer.* 48 (4), p. 1947, pl. II, Figs. 3-4, pl. 14, Fig. 3.

Description.—Colonies are compound and united laterally with other colonies. The laminae are irregularly convex upwards and concentric in cross-section. In a few forms the laminae may be regularly convex. But as growth proceeds the laminae pass up into an irregularly convex arrangement. Marginal crowding is a feature of this group of forms and pronounced constriction is seen in longitudinal section. In most specimens silicification has destroyed all but the coarsest lamination.

Specimens occur at Moora, Watheroo, Gunyidi (Fairbridge 1950) in chert; at Coorow Cave in dolomitic limestone and in silicified erratics in the Sakmarian Nangetty Formation. The stromatolites at Coorow Cave are exposed in 20 feet of dolomitic limestone (part silicified) with interbedded orthoquartzites. The limestone is overlain by silty orthoquartzites which have abundant oscillation ripple marks. The stromatolite growth is a biostromal, bedded deposit with a very open lamination.

Collenia columnaris Fenton and Fenton

Plate II, Fig. 2

Fenton, C. L., and Fenton, M. A., 1931, Algae and algal beds in the Belt Series of the Glacier National Park. *J. Geol.* 39, p. 680, pls. 1 and 2.

Fenton, C. L., and Fenton, M. A., 1937, Belt Series of the north: stratigraphy, sedimentation, palaeontology. *Bull. Geol. Soc. Amer.* 48 (4), p. 1941, pl. 9, Figs. 1-2.

Description.—Colonies exhibit a wide range in size; irregularly concentric in cross-section the forms range from 5 mm up to 80 mm in diameter and in longitudinal section from 20 mm to 30 cm (height). The laminae are regularly convex upwards. The long axis of the colonies may be at a steep angle to the bedding. No microstructure is evident save the lamination.

This morphotype occurs in silicified dolomitic limestone erratics in Becketts Gully of the Irwin River area and also occurs with the tubular coral-like problematica in the Noondine Member at Moora.

Cryptozoon frequens Walcott

Plate II, Fig. 3

Walcott, C. D., 1906, *Bull. Geol. Soc. Amer.* 17, pl. II. *Collenia ? frequens* Walcott, C. D., 1914, *Smithson. Misc. Coll.* 64, p. 113, pl. 10, Fig. 3.

Collenia frequens Fenton, C. L. and Fenton, M. A., 1931, *J. Geol.* 39, p. 685, pl. 8, Fig. 1.

Description.—Ovoid bodies standing with the long axis at an angle to the bedding; ranging in size from 5 cm to 1 metre in the diameter of the short axis. Crude concentric laminae are grouped around an axial plate or column which is parallel to the long axis of the colony. The outer laminae of colonies may be confluent and

some forms appear to have two structureless nuclei. The form occurs in a biohermal growth at Coomberdale and specimens have been collected from a chert breccia at Watheroo.

Fossilum problematicum

Plate II, Fig. 4

Three horizons of the Coomberdale Chert (units 3, 6 and 17 of the type section) contain a tubular colonial organism which has not been identified due mainly to the poor state of preservation of the remains. The problematicum has been submitted to two authorities and different interpretations have been obtained from each. Possible affinities include the tabulate corals, stromatoporoids or algae.

The specimens are completely silicified and consist of numerous closely spaced polygonal tubes with diameters of 2 to 3 mm. The tubes begin at a central holdfast and radiate upwards and outwards as growth proceeds. The outer tubes radiate almost horizontally before assuming a crowded upward growth which simulates some of the tabulate corals in megascopic view. The tube walls are composed of dense fine-grained microcrystalline quartz (chert) with detrital quartz (sand) grains and a few "heavy" minerals incorporated into the mass. The tubes are infilled with coarser-grained microcrystalline quartz with a few patches of normal quartz. The coarser material probably represents post-lithification infilling of former hollow tubes. No intermural structure is evident.

The pre-silicification wall may be pictured as an agglutinate structure with sand grains set in a calcium carbonate base. No corals or stromatoporoids are reported with agglutinate wall structure and the choice lies between two groups, the worms or the algae. The branching behaviour and the presence of a holdfast points to the algal affinities of the organism. The tubes can then be interpreted as lime encrustations around tubular thalli. From the ecological analysis of one problematica biotope (Table I) it is shown that considerable quantities of detritals were in suspension at certain times; the sediment gathering capabilities of the algae are well known and detrital grains impinging onto the thalli would probably be incorporated into the wall structure.

The external similarity of the form to the early tabulate corals has led to the assumption of a lower Palaeozoic age for the Coomberdale Chert (Öpik and Gilbert-Tomlinson 1955). However, if the affinities are algal then the age possibilities range from Precambrian to Recent. At least it can be established that the Moora Group is older than Sakmarian (L. Permian) on stratigraphic grounds. The Moora Group is intruded by dolerite dykes which Prider (1952) believes are probably Upper Proterozoic or Lower Cambrian in age; if this is correct then the age of the Moora Group can only be Precambrian, probably Proterozoic. This dating would also explain the complete lack of organisms other than algae in the Moora sediments which from environmental analysis should contain rich invertebrate faunas if they were deposited later than the Lower Cambrian.

Geological Structure

The Moora Group lies within a fragmented terrain structurally dominated by the Darling Fault. Subsidiary strike faults paralleling and dipping in towards the master rift have a general west-block-down movement similar to the movement on the main fault.

The Darling Fault which forms the present day western edge of the West Australian Precambrian Shield is the major line of crustal weakness of the area, indeed it is one of the larger structural features of the Earth's crust with strong negative gravity anomalies in the west indicating a marginal subsidence in the order of 20,000 to 40,000 feet (Thyer 1951). To the east of the fault the Archean granite and gneiss basement complex unconformably underlies the Moora Group sediments which are only preserved in a narrow 2 to 3 mile wide shatter zone immediately adjacent to the main fracture.

A rapid concentration of gravity anomaly lines (Thyer and Everingham 1956) from the central Perth Basin towards Moora and running thence along the western edge of the Moora Group outcrop via Jingemina to Coorow is an expression of the steep rise of the basement along the fault zone. The proximity of the Darling Fault to Moora is confirmed by the presence of Jurassic continental sediments 615 to 1,195 feet in a deep bore (2,230 feet) situated at approximately 1½ miles west of the Moora townsite.

The Moora Group sediments form a homoclinal structure within the Darling shatter zone with an average regional dip of 15° W.S.W. to W. There are localised changes in dip direction and magnitude adjacent to faults, the dip in the extreme case may become as much as 50°. The older Archean granites and gneisses underlying the sediments are probably folded on north-north-west to south-south-east trends with variations to north-south. This is in accord with the general north-north-west to south-south-east trend in the Western Australian Precambrian Shield (Prider 1952).

High angle normal or gravity faults are the main structural type in the Moora Group strata; these faults have a north-north-west trend and are sometimes slightly oblique to the strike of the sediments. The fault zones dip steeply (60°-70°) west toward the Darling rift. Movement is west-block-down which results in faulting-off of Moora Group formations and members; stratigraphic throws vary between 400 and 1,500 feet. East-west tensional stress must be regarded as the factor involved in faulting and surface manifestations are accordingly restricted to narrow shear zones, narrow zones of fault breccia, localised drag folding in adjacent sediments and by stratigraphic discrepancy.

A generation of faults with south to south-west trends, oblique to the sediment strike has the effect of breaking the area into a number of fault blocks, while still retaining the homoclinal and 15° W.S.W. to W. regional dip in the sedimentary strata. These faults are probably vertical or dip steeply. The oblique faults could result from a slight transeurrent movement (west-block-south) on the Darling Fault coupled with the main gravity (west-block-down) displacement. The surface manifesta-

tions in the dipping strata are the offsetting of sedimentary contacts, drag folding, and dip reversal in the Dalaroo Siltstone. The strike faults are also offset by this oblique faulting, but it is considered that both oblique and strike movements were probably synchronous and represent a post-Moora Group phase in the Darling Fault movements which fractured the eastern and upthrown wall of the Darling Fault into a series of fault blocks.

The movements in the meridional belt adjacent to and east of the Darling Fault between Moora and Coorow are normal faulting and due to east-west tensional stress which may have arisen from either reverse faulting or normal faulting in an underlying and deep-seated master fault (the Darling Fault). No structural evidence exists in the Moora Group strata which indicates the post-Moora Group compressional phase of the Darling earth movements discussed in McWhae *et al.* (1958). The dating of the faulting is very doubtful as palaeontological data regarding the age of the Moora Group are lacking. Quartz dolerite dykes intrude the basal crystalline complex and the Moora Group sediments; there is no displacement of these dykes by either the strike or oblique faults in the Moora Group outcrop so that the fault movements are indicated as pre-dolerite. The dolerite dykes, presumably due to a single taphrogenic episode are regarded as Upper Proterozoic or Lower Cambrian in age by Prider (1952). However, this dating has been questioned by McWhae *et al.* (1958) and until an unequivocal dating of both dolerites and Moora Group is obtained the chronology of the movements must remain a matter of speculation.

Folding in the Moora Group sediments is limited to drag effects adjacent to fault zones. Of the formations the Dalaroo Siltstone is the most susceptible to folding; this phenomenon and bedding plane slippage is a distinct characteristic of the formation. In all cases observed in the field, drag is formed by slippage and indicates the general west-block-down movement in the area.

Conclusion

The geological history of the western edge of the Western Australian Precambrian Shield between Moora and Coorow can be outlined as follows:

1. Formation of the Archean crystalline basement.
2. Deposition of the Capalcarra Sandstone accompanying warping of the craton edge with marine transgression and reworking of the regolith overlying the crystalline basement. Seismic activity and intrusion of sandstone dykes.
3. Deposition of the Dalaroo Siltstone with associated vulcanism and instability.
4. Deposition of the Mokadine Formation with faulting and vulcanism.
5. Deposition of the Coomberdale Chert, limestones, quartz sandstones, oolites; with stromatolite growth, slumping and brecciation. Shallow-water conditions with slow subsidence and slow deposition.

6. Further deposition is not recorded in the Moora Group sequence.
7. Faulting with gravity faulting and fragmentation of the sequence.
8. Silicification and formation of chert.
9. Taphrogeny with dolerite intrusion.
10. Erosion to present day topography.

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Part 2

4.—Description of a New Fish of the Family Galaxiidae from
Western Australia

By G. F. Mees*

Manuscript received—22nd November, 1960

A new species of the family Galaxiidae from the south-west of Western Australia is described. It sharply differs from other members of the family in shape of the fins, number of fin-rays, and particularly in having scales on the body. The habitat is a very small creek in heavy forest.

In July, 1959, the Western Australian Museum received from Mrs. E. Godridge of Shannon River, in the south-west of Western Australia, a small fish for identification. In an accompanying letter Mrs. Godridge wrote that the specimen had been caught in a creek near Shannon River and that she was forwarding it because it was unfamiliar to her.

It was at once evident that the specimen belonged to the Galaxiidae or some closely related group, and that it could not be referred to any species known from Western Australia. Owing to my absence from Perth the matter had to rest for a while, but later Mrs. Godridge was contacted again with the result that in October 1959, together with Miss K. C. A. Vollprecht and Miss H. Williams (both of the staff of our museum), I went to Shannon River, where Mrs. Godridge took us to the locality where she had caught the fish. Several hours of work resulted in the four of us obtaining, between ourselves, five additional specimens.

The material evidently represents a very distinct new species that will be described below.

The greatest credit is due to Mrs. Godridge, who not only obtained the first specimen in a habitat where few people would search for fish, but who moreover realised at once that it was something unusual, preserved it, and sent it to the Western Australian Museum.

Though I favour large genera wherever possible, the species presents such characters that it seems impossible to place it in any of the extant genera of the Galaxiidae.

Genus *Lepidogalaxias* genus novum

Characterised by the presence of rudimentary scales. Scales are otherwise unknown in the Galaxiidae. Further by the small number of rays in D and V, and by the great length of these rays. All fin-rays, with the exception of an odd one in the caudal fin, simple. Other characters are given in the species diagnosis.

Western Australian Museum, Perth, Western Australia.

Type of the genus:

Lepidogalaxias salamandroides species nova*

D 5-6, A 11-12, P 10-12, V 4, C 12-15, scales or scale-rudiments about 75-80 in a longitudinal line.

A slender Galaxiid of apparently small size; anterior part of the body more or less cylindrical, posterior part, behind implantation of D and A very much compressed. Head 4.3 to 5.0 in standard length; snout blunt, shorter than eye, about 0.5 to 0.7 of eye diameter; eyes small, 4.2 to 4.7 in head, in anterior part of head; nostrils in front of eye, rather close together, the anterior nostril near the margin of the upper lip, posterior nostril in front of middle of eye, above and posterior to anterior nostril; mouth small, cleft well below eye, maxilla reaching to below posterior half of eye, lips slightly fleshy; teeth uniserial in both jaws, no canines; a single series of comparatively large teeth on vomer and entopterygoids; tongue free, slender, evenly rounded anteriorly and as far as I could ascertain toothless; opercles large, free from isthmus, their posterior margins evenly rounded, soft and flexible (in the figure it looks as if there is a dent in the opercle, but this is only seemingly so; it is the place where the hind border of the opercle is lifted up by the slightly swollen base of the pectoral fin).

Scales. Fairly distinct on the sides of the body, less distinct dorsally and probably absent from the under surface; head and breast naked. Originally I thought that the sides had only regularly arranged dermal folds, but closer examination revealed that each fold consists of a very thin cycloid scale, covered by skin.

Lateral line present, but indistinct, particularly so on the posterior part of the body.

Dorsal fin slender and long, pointed with a very short base, consisting of five or six undivided rays, of which the third is the longest, implanted well backwards, with its origin over the anus.

Anal fin comparatively short and pointed, with a fairly long base, consisting of six well developed rays, the fourth of which is the

* The specific name is given because of a striking superficial similarity the species has to some smaller newts.

longest, and five or six small and thin rays, which are implanted close together but remain perfectly discernible as separate units. Anterior margin of A just behind anus and very slightly posterior to anterior margin of D.

Pectoral fins small, rounded, not reaching half way to implantation of ventrals, with ten to twelve undivided rays, base concealed under dermal flap of opercle, slightly ventral in position (distance from dorsal outline about twice distance from ventral outline).

Ventral fins with only four very long and slender undivided rays, the third of which is the longest and reaches beyond the anus; fins therefore strongly pointed and filamentous towards the tips; implantation in anterior half of the body, slightly farther back than two-fifths of the standard length.

Caudal fin rather elongate, consisting of twelve to fifteen rays, undivided or an occasional one divided, the middle rays longest, so that the tail looks evenly rounded or even slightly pointed (as is the case in the type specimen, see Fig. 1a).

From D and A backwards to C run dermal keels which, however, are not nearly as highly developed as in some other species of the family.

Colours. As regards coloration, the material at hand can be divided in two groups; these differ also in body shape.

The first group which includes the type and two other specimens, is brownish above, pale below, and has a very distinct broad longitudinal band, dark greyish blue in colour, along the sides, and two lines of the same colour on the head; one from the snout, through the dorsal part of the eye on to the upper margin of the opercle, the second from the postero-ventral part of the eye backwards. Apart from that, there are a few dark spots, concentrations of melanophores, on the head and irregularly distributed over other parts of the body.

The second colour type, to which the other three specimens belong, is mainly distinguished by the fact that the striking bluish colour is entirely absent; the band along the sides is less clear, at places interrupted, and brownish grey in colour; in one specimen it consists of a double series of brownish grey dots only, which makes the fish look strikingly different from the first colour type. The fishes of this colour are very much thinner than those of the first type, also their fins, particularly the tails, are strongly worn. I regard it as likely that the first colour type belongs to fishes in nuptial coloration, and that the second, duller type, is found in fishes after spawning. On dissection of a specimen of this group, I failed to locate the gonads which must have been small.

The type specimen, but none of the others, has a rodlike tubular organ protruding from the anus (Fig. 1a). On dissection this specimen was found to be a female, the abdominal cavity is filled with large eggs, each of over a millimetre in diameter. I preferred to leave the eggs *in situ* so that an exact count could not be made, but they number about twenty. It is possible that the rodlike tubular organ is an ovipositor. Several other specimens, at least one of which is a male, have a much more compli-

cated structure that can be described as follows (Fig. 1b and c): just before the anal pore the skin of the belly ends in two small papillae; behind the anus the anal fin is almost entirely encased in two dermal flaps (without removing at least one of these flaps it is impossible to count the anal rays as they are entirely concealed); two other dermal flaps also find their origin just behind the anus, and partly cover the first set of dermal flaps, partly cover the lower part of the sides of the body, above the anal fin. The function of these structures is as yet obscure to me.

I have been unable to find any trace of mucous pores, usually so conspicuous in Galaxiidae, on the upper surface of the head.

Type, a female specimen of 60 mm total length, 49 mm standard length, collected in July 1959 by Mrs. E. Godridge in a tiny creek about six miles E.N.E. of Shannon River. W.A.M. regd. no. P. 4887.

Paratypes, five specimens of 37, 48, 50, 54, 55 mm total length and 31, 39, 44, 47 and 47 mm standard length, collected on October 3rd 1959 by Mrs. E. Godridge, G. F. Mees, Miss K. C. A. Vollprecht and Miss H. Williams, at the same locality. Three specimens W.A.M. regd. no. P 4888, two specimens in the Leiden Museum.

Distribution. Known from the type locality only.

Habitat. Type and paratypes were obtained in a very small creek in heavy forest of mixed Karri and Jarrah (*Eucalyptus diversicolor* F. v. Muller and *E. marginata* J. E. Smith) about six miles E.N.E. of Shannon River (Plates I and II), in a place where the creek crossed a rarely used car-track. The creek was on an average about 30 cm wide and 5 cm deep; the creekbed was largely filled with *Eucalyptus* leaves, especially on those places where the creek was slightly wider and deeper. It was by taking out this layer of leaves mixed with some mud, and carefully going through it, that we obtained our specimens. Even then they were not easy to find as they did not wriggle. Not a single specimen was seen free swimming.

The only other aquatic animals found in the creek were large numbers of *Cherax preissii* Erichson, varying in size from 7 to 38 mm carapace length.

The creek is probably permanent, the water is cool and fairly rapidly flowing. The five fishes obtained in October were taken to the museum alive. They lived in an aquarium for a week, but after a fairly hot weekend were all found dead. I do not know whether lack of oxygen or the rise in temperature, or both these factors combined, caused their death. In the aquarium they would quietly rest on the bottom most of the time, usually concealed under some leaves, and always difficult to see.

Discussion. The discovery of a new species of the family Galaxiidae in Western Australia in itself is not surprising. When Regan (1906) published his revision he was able to list 14 species for Australia and Tasmania; in Munro's handbook (1957), 27 forms (24 species and 3 subspecies) are included, the majority of the additional species having been described during the last 25 years.

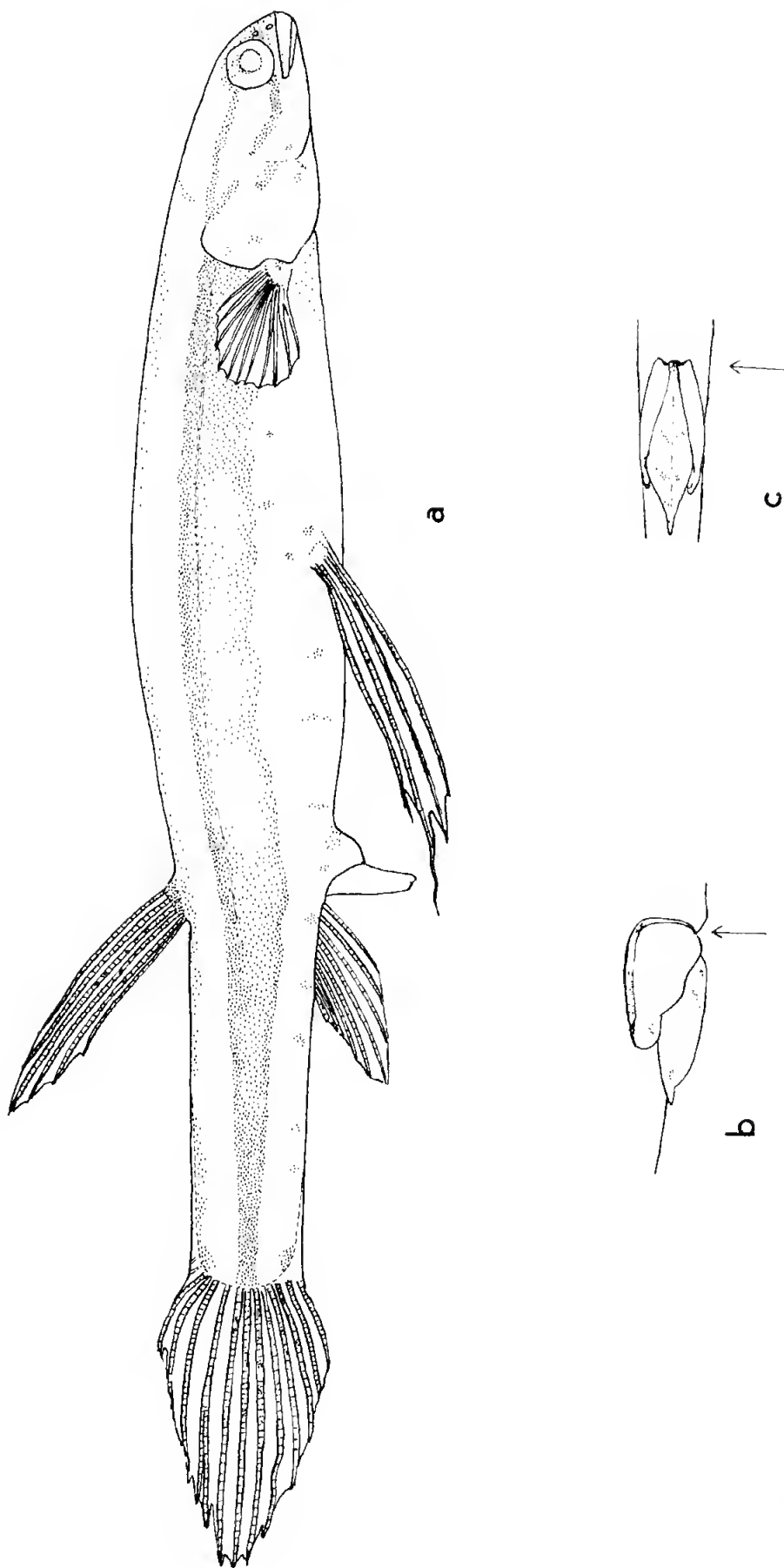


Fig. 1.—(a) *Lepidogalaxias salamandroides* ♀, type, $3 \times$ nat. size. To avoid overcrowding of the figure, the scales have not been indicated.
 (b) *Lepidogalaxias salamandroides* ♂, paratype of 44 mm standard length, anus and dermal flaps encasing anal fin, from right, $3 \times$ nat. size. The arrow points to the anus.
 (c) Same from below, $3 \times$ nat. size.



PLATE I
Type locality of *Lepidogalarias salamandroides*. The bucket stands in the stream. (Photograph: H. Williams.)



PLATE II

Type locality of *Lepidogalaxias salamandroides*. The footprint on the foreground gives an idea of the tinyness of the stream. (Photograph: H. Williams.)

From Western Australia, until quite recently, only one species, *Galaxias occidentalis* Ogilby (1899) was known; subsequently *Galaxias truttaceus hesperius* Whitley (1944) and *Galaxias pusillus nigrostriatus* Shipway (1953)* were added, both representatives of species known from the eastern states. In view of the richness of Tasmania and Victoria, one would expect even more species to be found in Western Australia. On the other hand there is little doubt that the unusual habitat has contributed to *L. salamandroides* not having been discovered earlier.

The aberrant nature of the species made me eager to have an independent opinion on it, and therefore two specimens were forwarded to the Leiden Museum where Dr. Boeseman examined them. Dr. Boeseman, in litt., 20. IX. 1960 agrees that the species belongs to the Galaxiidae, and that it deserves to be placed at least in a genus of its own, perhaps even in a separate subfamily. He kindly confirmed that scales are present, and suggested that I should examine other species of the family in search of scale rudiments. I have examined the three Western Australian species of *Galaxias* and found that they all have perfectly smooth skins without any trace of squamation.

* This species is nowadays usually placed in a separate genus *Brachygalaxias*, originally created for a South American species with five-rayed ventrals (Scott

1942, Stokell 1954, Munro 1957). However, Shipway described *G. p. nigrostriatus* as having V 1 + 5, which is six. Apart from the type the Western Australian Museum has only one specimen of this form, collected at Northcliffe near Albany on August 9, 1960, by Mr. W. H. Butler, no. P 4901, and it, also, has six-rayed ventrals. Stokell (1945) has already shown that the number of ventral rays is a character of doubtful systematic value, and for the moment I prefer not to give an opinion on the validity of *Brachygalaxias*.

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5.—Tertiary Microplankton from the Rottnest Island Bore, Western Australia

By Isabel C. Cookson* and A. Eisenack†

Manuscript received—21st June, 1960

Twelve species of microplankton are recorded from two samples from the Rottnest Island Bore. One new genus (*Rottnestia*), 4 new species (*Wetzeliella intermedia*, *Leptodinium maculatum*, *Rottnestia simplicia*, *Hystriosphæridium paucifurcatum*) and 2 new subspecies (*Deflandrea phosphoritica* subsp. *australis*, *Hystriosphæridium floripes* subsp. *breviradiatum*) are described. The age of the deposit between 1,480 and 1,595 feet is discussed.

Introduction

The occurrence of well-preserved spores, pollen grains and microplankton in core samples from Rottnest Island, Western Australia, was recently recognized by Mr. B. E. Balme and Mr. C. W. Hassell of the University of Western Australia.

We are deeply indebted to Mr. Balme for giving us the opportunity of studying the microplankton content of two samples from 1,480-1,541 feet and 1,575-1,595 feet in the Rottnest Bore, and for stratigraphic information. The necessary preparations for this work were made by one of us (I.C.C.) at the Institute for Geology, Blindern, Oslo, and we wish to thank Professor O. Arbo Høeg for the facilities he so freely provided.

Most of the types in these two samples have been identified and where necessary described, but a few have had to be omitted on account of rarity, delicacy, or poor preservation.

The exact age of the Rottnest Tertiary sediments is still uncertain. Mr. D. J. Belford in an unpublished report to the Bureau of Mineral Resources, Canberra gives an Upper Eocene age on the basis of Parr's (1937-38) work on the Kings Park Shale of the Perth area. However a suggestion put forward by Crespín in Coleman (1952) that the latter may be of Paleocene age raises the question as to whether the age of the Rottnest deposits, if they correlate with the Kings Park Shale, may not also be Paleocene.

Although this question cannot be resolved by the present contribution, the evidence provided by the microplankton, when taken in conjunction with that of the spores and pollen grains associated with it, indicates that the Rottnest deposits at the depths studied are younger than the Pebble Point Formation of Victoria the age of which is believed to be Lower Tertiary with Paleocene affinities (Baker 1953; Baker and Cookson 1955).

The occasional occurrence in our preparations of a few types of microplankton which, hitherto, have only been found in Upper Cretaceous sedi-

ments has led us to consider whether they are natural components of the Rottnest assemblages or contaminants or remanié fossils. At present we are inclined against the idea of their extension into the Eocene and therefore have not recorded them as members of the Rottnest assemblage. A list of these Cretaceous types is given under a separate heading.

Systematic Descriptions

Dinoflagellates

Family DEFLANDREIDAE

Genus *Deflandrea* Eisenack 1938

Deflandrea phosphoritica Eisenack subsp. *phosphoritica*

(Plate I, Figs. 1, 4)

Deflandrea phosphoritica Eisenack 1938, p. 187, Fig. 6.

Well preserved examples which come within the range of *D. phosphoritica* as described by Eisenack (1938) from the Amber Formation of Samland, East Prussia are relatively numerous in both Rottnest samples. They agree also with specimens identified as *D. phosphoritica* by Manum (1960) from a Lower Tertiary deposit in Spitsbergen in the variable degree of granulation of the outer membrane, the ornamentation of the internal body including the presence of the smooth or less granular dorsal and ventral areas of the internal body and the indication of the longitudinal furrow.

Dimensions.—Length of shell 103-120 μ , breadth 82-100 μ .

Known Geological Range.—*D. phosphoritica* has been recorded from a Lower Tertiary deposit at Birregurra, Victoria, Australia (Deflandrea and Cookson 1955). Its range in Europe is from Paleocene to Middle Oligocene (Alberti 1959, Gerlach 1961).

Deflandrea phosphoritica subsp. *australis* subsp. nov.

(Plate I, Figs. 2, 3; holotype Fig. 2 Nat. Mus. Vict. P20537)

Specimens which differ in certain constant characters from typical examples of *D. phosphoritica* are not uncommon in the Rottnest deposit between 1,480 and 1,541 feet. However, these features do not seem of sufficient importance for specific separation. A new subspecies is therefore proposed for them on the basis of the following differences from the type:— (a) the theca is proportionally longer and narrower; (b) the outer membrane is more closely and coarsely granular especially in the

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apical and antapical regions; (c) the horns are more sharply pointed; (d) the apical horn is surmounted by a well-defined solid cylindrical process; (e) the longitudinal furrow is more clearly marked and can be traced downwards from the lower borders of the girdle, the left hand ridge sometimes being straighter than the right hand one.

Dimensions.—Type—length 146μ , breadth 94μ , internal body $71 \times 80\mu$. Range—length $105\text{--}146\mu$, breadth $83\text{--}102\mu$.

Genus *Wetzelicella* Eisenack 1938

Wetzelicella lineidentata Deflandre and Cookson

(Plate I, Fig. 7)

Wetzelicella lineidentata Deflandre and Cookson, 1955, p. 253, Plate V, Fig. 5.

This species, hitherto known only by one imperfect specimen from a Lower Tertiary deposit near Denmark, Western Australia, occurs in the Rottneest deposits between 1,480 and 1,541 feet and 1,575 and 1,595 feet.

The new examples show that, as Deflandre and Cookson (1955) suggested, the epitheca is triangular in shape with straight or slightly concave sides and that the apical horn is not strongly developed. The shells are approximately as broad as long and usually show indications of a girdle as low ledges, especially in the region of the lateral horns, or as two rows of blunt spines. In a few specimens the marginal denticulation agrees with that of the type in others (Plate I, Fig. 7), the teeth are more strongly developed. Distinct fields, which are delimited by rather prominent teeth, are evident in most specimens, but the tabulation is not a true one.

Dimensions.—Length $148\text{--}152\mu$, breadth $113\text{--}152\mu$.

Wetzelicella intermedia sp. nov.

(Plate I, Figs. 5, 6; holotype Fig. 5 Nat. Mus. Vict. P20538)

Description.—Shell flat, usually somewhat longer than broad, rounded-rhombic in outline with slightly convex to nearly straight sides and a broadly rounded apex with one or two centrally placed teeth. The lateral horns are represented by slight, broadly-rounded or indented expansions of the outer membrane; a single short pointed horn is developed to one side of the antapex. A circular girdle which crosses the shell in its broadest region is indicated by low ledges or folds especially at the lateral margins or by two rows of short teeth. The margins of the shell are smooth or slightly

wavy or toothed the dorsal and ventral surfaces are either smooth or sparingly dotted, the dots sometimes outlining fields comparable with those of *W. lineidentata*. The internal body is large, flat, and oval in outline its wall is thin and in optical section is seen to be composed of small, closely arranged rods. A large squarish pylome is situated in the epitheca.

Dimensions.—Type—length 125μ , breadth 122μ ; internal body $100 \times 100\mu$. Range—length $111\text{--}143\mu$, breadth $97\text{--}130\mu$.

Comments.—*Wetzelicella intermedia* as its name suggests, seems to be a form intermediate between *W. lineidentata* and *W. glabra* Cookson. The slightly denticulate margins and surface thickenings, sometimes linearly arranged so as to enclose fields, indicate a certain relationship with *W. lineidentata*, on the other hand the practically smooth margin and surface of other examples suggests an affinity with *W. glabra*. In the oval shape of the shell and the reduced form of the horns *W. intermedia* is distinct from *W. lineidentata* and *W. glabra*.

W. intermedia agrees with *W. rhomboidea* Alberti (1961) in certain features, but the latter species has no indication of spines.

Family GONYAULACIDAE

Genus *Leptodinium* Klement 1960

Leptodinium maculatum sp. nov.

(Plate II, Figs. 5, 6; holotype Nat. Mus. Vict. P20539)

Description.—Shell oval to nearly spherical, without a horn. Girdle equatorial, strongly helicoid and rather broad with low borders. Longitudinal furrow broad, elongate-rectangular, bounded antapically by a large plate. Plates strongly outlined, bordered by low, thin, hyaline ledges. Surface of the plates distinctly dotted. Pylome formed by removal of plate 3''. Tabulation 4'', 6'', 5'', 1 p, 1''''.

Dimensions.—Type 52μ long, 50μ broad. Range. Length $52\text{--}64\mu$, breadth $48\text{--}60\mu$.

Comments.—*L. maculatum* is close to the Upper Oligocene species *L. membranigerum* Gerlach 1961 from north-western Germany. However the latter can be distinguished from the Rottneest species by its more elongated egg-shaped form, the higher ledges and the finely granular surface of the plates.

Family incerta

Genus *Rottneestia* gen. nov.

Description.—The shells consist, like those of a number of fossil dinoflagellates, of an internal body and a thin outer membrane. The

PLATE I*

Fig. 1.—*Deflandrea phosphoritica* Eisenack, \times ca. 430, P 20554.

Figs. 2, 3.—*Deflandrea phosphoritica* subsp. *australis*, subsp. nov., Fig. 2, type \times ca. 430, P 20537; Fig. 3, another example showing longitudinal furrow \times ca. 330, P 20553.

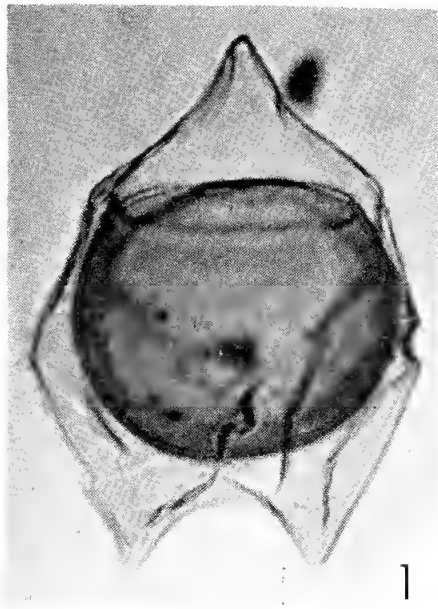
Fig. 4.—*Deflandrea phosphoritica* Els. Ventral surface of internal body showing "smooth" area \times ca. 500, P 20552.

Figs. 5, 6.—*Wetzelicella intermedia* sp. nov.; Fig 5, type \times 450, P 20538; Fig. 6 a mere highly ornamented specimen \times ca. 400, P 20553.

Fig. 7.—*Wetzelicella lineidentata* Deflandre and Cookson \times 450, P 20550.

Figs. 8-10.—*Rottneestia borussica* (Eisenack). Fig. 8 one of the original specimens from the Amber Formation, East Prussia, \times ca. 400. Figs. 9, 10 highly ornamented examples from Rottneest Bore \times 380, P 20541, P 20551.

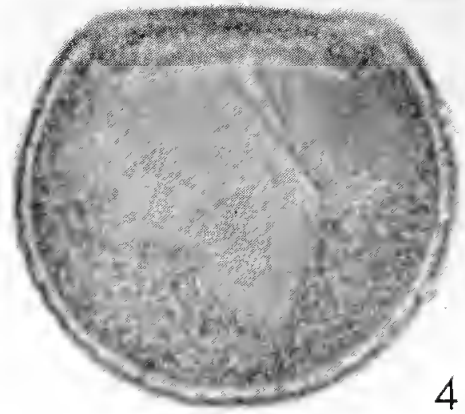
* The photographs in Plates I and II were taken by A. Eisenack. All are of specimens from the Rottneest Bore between 1,480 and 1,595 feet except Plate I, Fig. 8 which is from the Amber Formation of East Prussia. Registered numbers in the palaeontological collection of the National Museum of Victoria are given.



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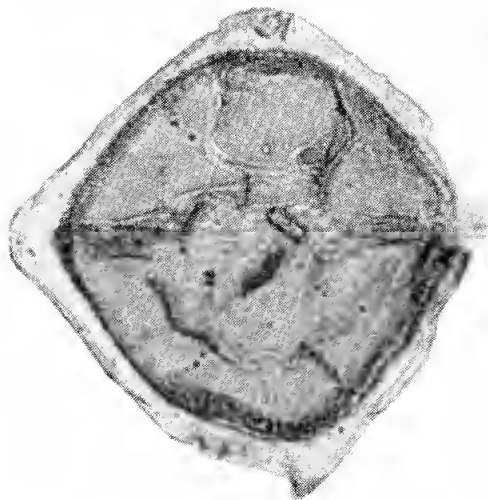
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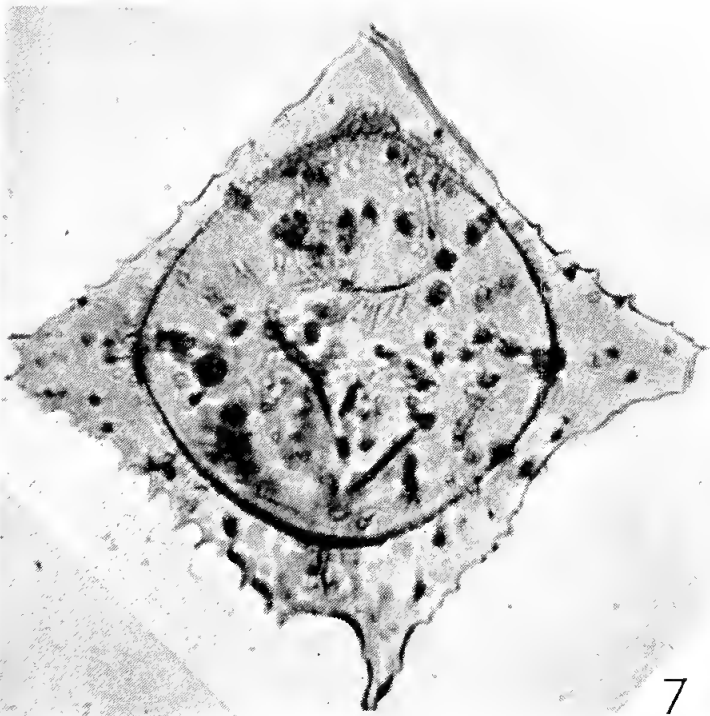
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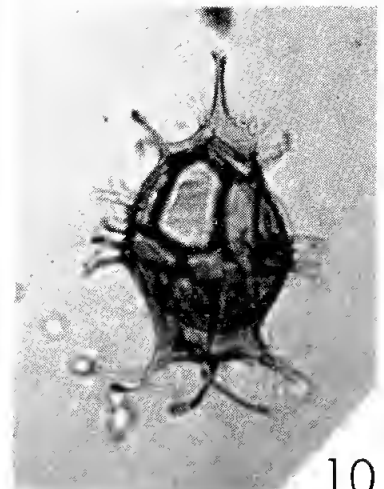
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PLATE I

internal body is clearly defined and oval in shape. The outer membrane is in contact with the internal body in the central region but extends beyond it both apically and antapically. The apical expansion is surmounted by a median conical or cylindrical horn; the antapical expansion is squarish in shape with sharp or rounded angles. The shell is crossed by a median helicoid girdle and a relatively broad longitudinal furrow runs obliquely across the ventral surface. The surface of the outer membrane is divided into pre- and post-equatorial fields the limits of which run into the edges supporting the apical and antapical expansions. Forked appendages may or may not be developed at the corners of the fields. A large elongate-trapezoid pylome develops on the dorsal side of the epitheca in both the internal body and outer membrane.

Type species *Hystrichosphaera borussica* Eisenack.

Rottnestia borussica (Eisenack)

(Figs. 1a, 1b, 1c, 1d; Plate I, Figs. 8-10; Plate II, Figs. 1, 2)

Hystrichosphaera borussica Eisenack 1954, p. 62, Plate IX, Figs. 5-7.

Hystrichosphaera borussica Eisenack in Deflandre and Cookson, 1955, p. 263, Plate V, Figs. 9, 10.

Rottnestia borussica was established in 1954 on 3 specimens two of which, including the type, had lost their apical expansions. The better preserved Rottnest examples from between 1,480 and 1,595 feet, which are obviously specifically identical with the German ones have thrown fresh light on this form both as regards the morphology and the affinity of the species. A new description based on both the German and Australian specimens is therefore given here.

Description.—Shell considerably longer than broad with a prominent internal body which is in contact with the outer membrane except at the poles. Both apical and antapical expansions of the outer membrane are usually strongly developed. The apical expansion narrows distally; its margins are rather deeply embayed and in perfect specimens it bears a well defined median cylindrical horn. The antapical expansion is broader, angular in section and is supported by 5 or 6 (usually 6) ledges. The girdle is clearly defined and crossed on the dorsal surface by vertical ledges which mark out transversely elongate-rhombic areas. The longitudinal furrow runs obliquely across the ventral surface from the base of the apical expansion almost to the upper limit of the antapex. Both the epitheca and hypotheca have

more or less clearly defined fields which, usually, are longer than broad; their boundaries run to the outer limits of the shell.

In the specimens from East Prussia and some of those from the Rottnest Bore forked appendages are developed at the corners of the fields. A few of the Rottnest examples have no appendages. A large pylome extends from the girdle almost to the upper limit of the internal body, the opening in the outer membrane coinciding with that of the internal body.

Comments.—As was mentioned by Eisenack in 1954 the three forms of *Hystrichosphaera* described by Deflandre 1937, i.e. *Hystrichosphaera speciosa*, *H. ovum* and *H. wetzeli* are probably all related to *Rottnestia borussica*.

In his description of *H. speciosa* Deflandre mentions "plaques cingulaires en helice levogyre" but since the figure given is of the dorsal surface it is not possible to judge whether a longitudinal furrow or longitudinally arranged fields were present. In *H. ovum* the apical and antapical expansions have the same construction as those of *R. borussica* but, apart from the development of a girdle, the figures give little information regarding the presence and arrangement of fields. In *H. wetzeli*, on the other hand, the ledges are developed as rather high membranes and there is a clearly marked girdle formed by elongate-rhombic fields as in *R. borussica*. The figured specimen shows the dorsal surface, but Deflandre, himself, speaks of a "direction des appendices qui soutiennent les voiles de la partie postérieure, direction qui est parallèle au grand axe de la logette et non rad'ante". It seems possible therefore that this longitudinal arrangement of the fields is also present on the "posterior" surface as in *R. borussica*.

However, only a further investigation of the three Cretaceous species will determine their relationship to *Rottnestia*.

Rottnestia simplicia sp. nov.

(Figs. 1e, 1f; Plate II, Figs. 3, 4; holotype Nat. Mus. Vict. P20541)

Occurrence.—Rottnest Bore at 1,575-1,595 feet.

Description.—Shell without appendages. Apical and antapical expansions of the same construction as those of *R. borussica* but less strongly developed, apical horn well marked. Longitudinal furrow distinct, broadening towards the antapex. Girdle, tabulation and pylome similar to those of *R. borussica*. The internal body is elongate-oval in outline.

Dimensions.—Type—Length 83μ , breadth 56μ , internal body $60 \times 38\mu$.

PLATE II

Figs. 1, 2.—*Rottnestia borussica* (Eisenack). Ventral and dorsal surfaces of a specimen without appendages \times ca. 500, P 20541.

Figs. 3, 4.—*Rottnestia simplicia* sp. nov. Ventral and dorsal surfaces of type \times ca. 500, P 20541.

Figs. 5, 6.—*Leptodinium maculatum* sp. nov. Ventral and dorsal surfaces of type \times ca. 700, P 20539.

Figs. 7, 8.—*Hystrichosphaeridium floripes* Deflandre and Cookson, Fig. 7 \times ca. 390, Fig. 8 \times ca. 450.

Fig. 9.—*Hystrichosphaeridium colligerum* Deflandre and Cookson \times ca. 500, P 20540.

Figs. 10, 11.—*Hystrichosphaeridium floripes* subsp. *breviradiatum* subsp. nov. at two foci \times ca. 400, P 20542.

Fig. 12.—*Cannosphaeropsis* cf. *caulleryi* Deflandre \times ca. 500, P 21304.

Figs. 13, 14.—*Thalissophora velata* (Deflandre and Cookson). Two para-types \times ca. 230, P 21302, P 20303.

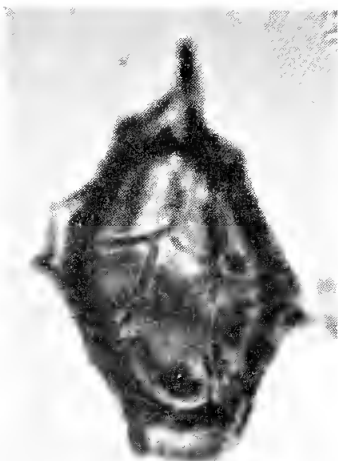
Fig. 15.—*Hystrichosphaeridium paucifurcatum* sp. nov., type \times ca. 240, P 20543.



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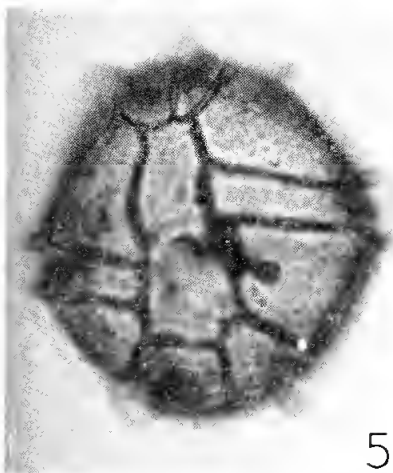
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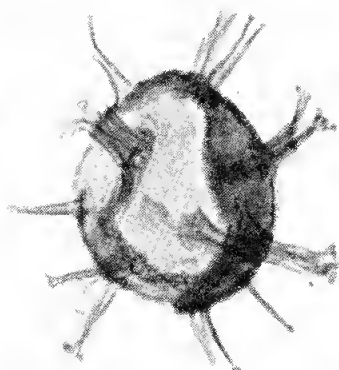
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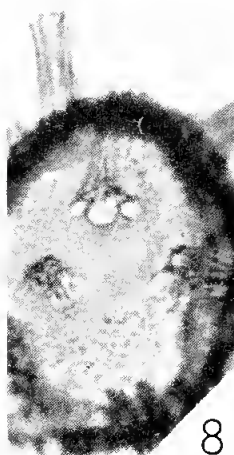
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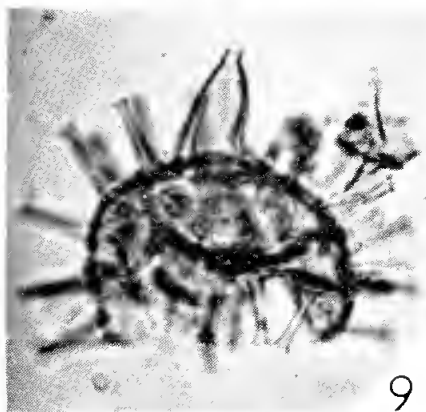
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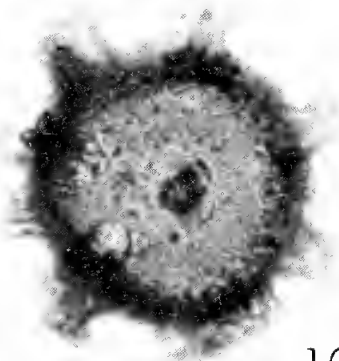
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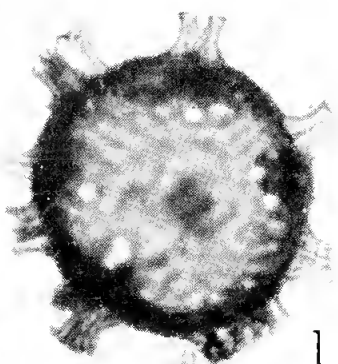
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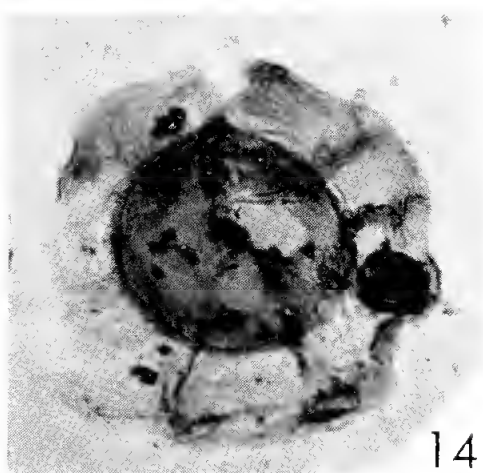
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12



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14



15

PLATE II

Comments.—This species is based on a single but well preserved specimen. In it the dinoflagellate characters are even more strongly marked than in *R. borussica*.

Hystrichospheres

Family HYSTRICHOSPHERIDAE

Genus *Hystrichosphaeridium* Deflandre 1936

Hystrichosphaeridium floripes Deflandre and Cookson

(Plate II, Figs. 7, 8)

Hystrichosphaeridium floripes Deflandre and Cookson 1955, p. 176, Plate VII, Figs. 1, 2, 7.

H. floripes is the most numerous individual type in the Rottneest Bore sample between 1,480 and 1,541 feet. It appears to be absent from the sample between 1,575 and 1,595 feet. The Rottneest examples agree in all respects with those occurring in the Lower Tertiary "Coffee Rock" from the Western Australian Government Railway Department's Bore 9 between 18 and 27 feet near Denmark, Western Australia (Deflandre and Cookson 1955).

Hystrichosphaeridium floripes subsp. *breviradiatum* subsp. nov.

(Plate II, Figs. 10, 11; holotype Nat. Mus. Vict. P20542)

Description.—Similar to *H. floripes* but with considerably shorter and proportionally broader appendages.

Dimensions.—Holotype—Overall diameter 86μ , diameter of shell 66μ ; appendages $10-15\mu$.

Comments.—This subspecies occurs in small numbers in the Rottneest sample between 1,480 and 1,541 feet.

Hystrichosphaeridium colligerum Deflandre and Cookson

(Plate II, Fig. 9)

Hystrichosphaeridium colligerum Deflandre and Cookson 1955, p. 273, Plate VII, Fig. 3.

The imperfectly preserved figured specimen is the only undoubted example of this species recovered from the Rottneest deposits. However the presence of a large cylindrical appendage in association with numerous smaller tubular processes leaves no doubt as to its affinity. It was recovered from the sample between 1,480 and 1,541 feet.

H. colligerum was described from specimens isolated from the Princetown Member of the Dilwyn Clay, Victoria, the age of which is believed to be Lower Eocene (Baker 1953).

Hystrichosphaeridium paucifurcatum sp. nov.

(Plate II, Fig. 15; holotype Nat. Mus. Vict. P20543)

Occurrence.—In the Rottneest Bore between 1,480 and 1,595 feet.

Description.—Shell spherical to slightly oval, thin-walled, faintly granular, closely covered with long, slender, solid appendages which taper gradually towards their slightly bifurcate apices. The fine fibrils of which the appendages are composed splay out slightly on the surface of the shell.

Dimensions.—Holotype—Diameter of shell $ca. 112\mu$ length of appendages $ca. 42\mu$ long.

Genus *Cannosphaeropsis* O. Wetzel 1933

Cannosphaeropsis cf. *caulleryi* (Deflandre)

(Plate II, Fig. 12)

Hystrichosphaeridium caulleryi Deflandre 1938, Trav. Sta. Zool. Wimereux, 13: 189, Plate XI, Figs. 2, 3.

Cannosphaeropsis caulleryi (Deflandre); Deflandre 1947, C.R. Acad. Sci. Paris, 224: 1576.

Cannosphaeropsis cf. *caulleryi* (Deflandre); Cookson 1953, Mem. Nat. Mus. Melb. 18: 117, Plate II, Figs. 35-40.

Cannosphaeropsis caulleryi (Deflandre); Deflandre and Cookson 1955, Aust. J. Mar. Freshw. Res., 6: 283, Plate VII, Fig. 8.

A few imperfect shells which appear to have similar characters to those of the Australian specimens referred by Deflandre and Cookson (1955) to the Jurassic species *C. caulleryi* have been isolated from the Rottneest samples between 1480 and 1541 feet.

The specimens identified by Deflandre and Cookson were recorded from the following Victorian deposits: Pebble Point Formation (Paleocene to Lower Eocene); Birregurra Bore at 842-843 feet (? Lower Eocene); Princetown Member of Dilwyn Clay (Lower Eocene); Anglesea Siltstone (? Middle Eocene).

Incertae sedis

Genus *Thalassiphora* Eisenack and Gocht 1960

Thalassiphora velata (Deflandre and Cookson)

(Plate II, Figs. 13, 14; holotype Nat. Mus. Vict. P16246)

Pterocystidiopsis velata Deflandre and Cookson, 1955, p. 291, Plate VIII, Fig. 8.

A careful study of the type specimen of *Pterocystidiopsis velata* from near Denmark, Western Australia, in the light of the better preserved specimens of a similar nature from the Rottneest samples has shown that the body is not enclosed by the delicate wing-like membrane to which it is attached. The type together with the Rottneest specimens, cannot, therefore, be included in the genus *Pterocystidiopsis* Deflandre since the body of the type of that genus lies completely within the outer membrane. On the other hand both the Denmark and Rottneest samples fall readily into the new genus *Thalassiphora* Eisenack and Gocht.

Description.—The shells of *T. velata* consist of a spherical to oval body and a thin and relatively wide saucer-shaped wing-like membrane. The body has a rather firm, faintly granular wall and a distinct pylome is developed. The body is attached to the central region of the wing by numerous root-like strands from which fibrils separate out in a fan-shaped manner.

Dimensions.—Body $ca. 95-105\mu$, diameter of wing $ca. 160-240\mu$.

Comments.—*T. velata* is close in all respects to *T. pelagica* (Eisenack) from the Amber Formation of Eastern Germany the only significant difference being the small tail-like projection at the periphery of the wing of the latter.

Eisenack and Gocht (1960) have recently removed *T. pelagica* from the genus *Pterospermopsis* W. Wetzel and established the genus *Thalassiphora* for Eisenack's *Pterospermopsis pelagica*.

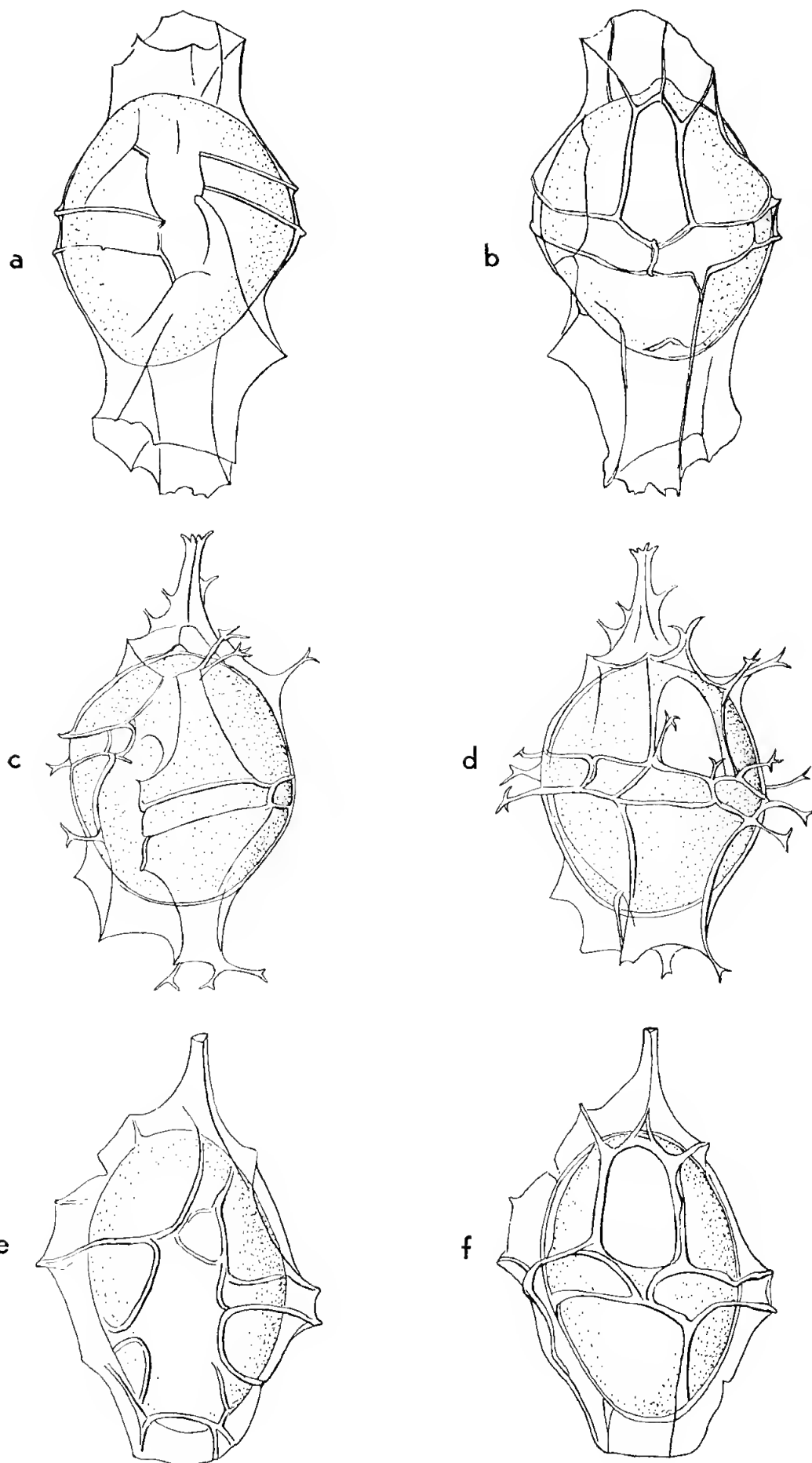


Fig. 1.—(a) and (b) *Rottnestia borussica* (Eisenack), ventral and dorsal surfaces of a specimen without appendages, \times ca. 640 (c) and (d) *Rottnestia borussica*, ventral and dorsal surfaces of a specimen with an apical horn and a few appendages, \times ca. 640 (e) and (f) *Rottnestia simplicia* sp. nov., ventral and dorsal surfaces of the same specimen, \times ca. 640.

Genus *Crassosphaera* Cookson and Manum 1960

Crassosphaera stellulata Cookson and Manum

Crassosphaera stellulata Cookson and Manum. Nytt Mag. Bot. Oslo, 8: 5-9.

This species occurs in the Rottnest Bore deposits between 1480 and 1595 feet. It has not been found elsewhere.

"Mesozoic" Types from the Rottnest Deposits

As already mentioned a few Mesozoic types have been observed in the Rottnest residues. All have been recorded from Western Australian deposits particularly from the Greensand of the Gingin area and the Osborne Formation of the Perth Basin. The significance of their occurrence cannot be determined without a thorough investigation of the deeper portions of the bore.

Microplankton

Gonyaulax hyalodermopsis Cookson and Eisenack from the South Perth Formation, Western Australia, Attadale Bore at 809 feet, Grierson Member of Birdrong Formation, Western Australia, Meadow Station Bore No. 9.

Deflandrea echinoidea Cookson and Eisenack from the Toolong Calcilutite, Western Australia; Wapet's Seismic Shot Hole B 1; north of Gingin, Western Australia, at 160 feet.

Nelsoniella aceras Cookson and Eisenack from the Toolong Calcilutite, Western Australia, (Senonian), Wapet's Seismic Shot Hole B 1, at 160 feet (Turonian to Middle Senonian); Nelson Bore at 5,304 feet, Victoria (Upper Cretaceous).

Nelsoniella semireticulata Cookson and Eisenack from Wapet's Seismic Shot Hole B1, at 120, 160 feet.

Nelsoniella tuberculata Cookson and Eisenack from the Toolong Calcilutite, Western Australia, Wapet's Seismic Shot Hole B 1, at 120, 160 feet.

Diconodinium dispersum Cookson and Eisenack from the Osborne Formation, Western Australia, Subiaco Bore at 358 feet.

Odontochitina porifera Cookson from the Toolong Calcilutite, Western Australia, Wapet's Seismic Shot Hole B 1 at 160, 170 feet; Nelson Bore, Victoria, at 6,233 feet.

Spores and Pollen Grains

Hoegisporis lenticulifera Cookson from Australian Upper Aptian to Cenomanian deposits including the Osborne Formation, Western Australia, Subiaco Bore at 358 feet and Wapet's Seismic Shot Hole B 1 between 190 and 220 feet.

Zonalapollenites dampieri Balme which is plentiful in the South Perth Shale and Upper Jurassic deposits in Australia and New Guinea.

Classopollis torosus Reissenger (seen by B. E. Balme) from the South Perth Shale and other Lower Cretaceous deposits.

Only one or two of the abovementioned types have been observed.

Stratigraphical Considerations

Evidence from Microplankton

Apart from indicating a Lower Tertiary age the small number of microplankton types present gives no precise indication of the age of the Rottnest samples.

One of the commonest species *Deflandrea phosphoritica* has a comparatively wide range in the Lower Tertiary of Europe, recent records having extended its range from Paleocene to Middle Oligocene. In Victoria *D. phosphoritica* has been recorded from a deposit in the Birregurra Bore at a depth of 876-877 feet. The age of this is certainly younger than that of the Pebble Point Formation (Paleocene to Lower Eocene, Baker 1953) and has been given as ? Lower Eocene (Cookson 1954).

In Europe the genus *Wetzeliella* has its main development in the Lower Tertiary with species ranging from Upper Paleocene to Upper Oligocene (Alberti 1961). *W. lineidentata* which occurs in the Rottnest deposit between 1,480 and 1,595 feet has been previously recorded from a deposit near Denmark, Western Australia. On its pollen content, the age of this is Lower Tertiary and definitely younger than that of the Pebble Point Formation (Paleocene to Lower Eocene). The deposit at Noarlunga, South Australia, in which *W. glabra* occurs, is of approximately the same age. This species is closely allied to the Rottnest species *W. intermedia*. *Leptodinium maculatum* of the Rottnest Bore is most closely related to *L. membranigerum* from Upper Oligocene beds in north-western Germany.

The only locality, apart from the Rottnest deposit between 1,480 and 1,595 feet in which undoubted examples of *Rottnestia borussica* have been found is the Upper Eocene Amber Formation of Samland, East Prussia. *Thalassiphora pelagica* also from the Amber Formation agrees closely with *T. velata* from the Rottnest Bore. *Hystriosphæridium colligerum* has been recorded from the Princetown Member of the Dilwyn Clay, Victoria (Lower Eocene).

Evidence from Pollen Grains

The pollen content of the Rottnest deposits as a whole is being studied by Mr. D. M. Churchill at the University of Western Australia and so will not be dealt with here in any detail. However, when the age of a deposit is in doubt as many microfossils as possible should be taken into consideration.

Three distinctive pollen species, all of which are components of "Microflora C" (Cookson 1954) in the Victorian and South Australian Lower Tertiary have been observed in the Rottnest deposit between 1,480 and 1,541 feet namely: *Proteacidites pachypolus* Cookson and Pike, *Beaupreidites elegansiformis* Cookson and *Anacolosidites acutulus* Cookson and Pike.

Proteacidites pachypolus has been advanced as the index fossil of "Microflora C" for beds higher in the Victorian Lower Tertiary succession than those of the Pebble Point Formation, but the exact age of the beds containing "Microflora C" has not been determined. *P. pachypolus* has been recorded from: (1) the carbonaceous silts+one at Anglesea, the age of which is given by Raggatt and Crespín (1952 p. 146) as ? Middle Eocene; (2) the basal clays of the Castle Cove section which may be Upper Eocene or older (fide Dr. O. P. Singleton); (3) the beds in the Nelson Bore at 992 feet which have been

dated as Lower Eocene (Baker and Cookson 1955) and (4) the Birregurra bore between 760 feet and 960 feet.

Anacolosidites acutulus, also a component of "Microflora C" has been recorded from the Birregurra Bore between 760 and 900 feet, and the Anglesea Siltstone. *Beaupreidites elegansiformis* occurs in an Eocene deposit at Alberton West (Cookson and Dettmann 1959) and in the Yallourn Brown Coal of ? Oligocene age.

Conclusions

Although the evidence from these two sets of microfossils is inconclusive, it shows that the Rottnest deposits are Eocene and clearly younger than the Paleocene to Lower Eocene Pebble Point Formation of Victoria. Further than this one cannot go until the beds in which "Microflora C" occurs are more reliably dated by other means. The Upper Eocene age suggested by Belford for the Rottnest Bore deposits on the basis of foraminifera is not incompatible with their pollen and microplankton content, but it is equally possible that they may have been somewhat older than this.

Correlation with the Carbonaceous Deposits near Denmark, Western Australia

In 1955 a small microplankton assemblage was recorded by Deflandre and Cookson from bore samples of a carbonaceous sandy deposit situated near the Hay-Denmark railway deviation, 354 miles from Perth, Western Australia. Associated with this assemblage were pollen grains some of which could be identified with types, including *Proteacidites pachypolus*, occurring in the "Microflora C" of south-eastern Australia.

The microplankton assemblages of the Denmark and Rottnest deposits, although not identical, are sufficiently similar, as will be seen from Table I, to permit a close correlation between them.

TABLE I

| | | | Rottnest Bore | Denmark Deposit |
|---|------|------|------------------|--------------------|
| <i>Deflandrea phosphorica</i> | | | + | — |
| <i>Wetzelietta lineidentata</i> | | | + | + |
| <i>Wetzelietta intermedia</i> | | | + | — |
| <i>Rottnestia borassica</i> | | | + | ? |
| <i>Hystrichosphaeridium floripes</i> | | | + | + |
| <i>Thalassiphora velata</i> | | | + | + |
| <i>Epicephalopyxis indentata</i> | | | — | + |

The occurrence in both deposits of the two distinctive species *Hystrichosphaeridium floripes* and *Thalassiphora velata* neither of which has, as yet, been found elsewhere is significant. All indications are that the Rottnest and Denmark deposits are of approximately the same age.

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Memorial

Benjamin Latimer Southern (1898-1960)

The late Mr. Southern was born on the 2nd of November 1898, and commenced a career in chemistry as part-time temporary junior assistant in the Laboratories of the Government Analyst in 1917. He also studied at the Perth Technical School and in 1924 was elected an Associate of the Australian Chemical Institute. In the same year he registered as an Analyst under the Public Health Act and was appointed to the permanent staff of the Government Chemical Laboratories. Early in 1926 Mr. Southern suffered a serious illness which incapacitated him for some six months. Until 1947 Mr. Southern's work was in the Agricultural Division of the Laboratories with particular application to soils, and in 1935 he was admitted as a corporate member of the Australian Institute of Agricultural Science.

In August, 1947, Mr. Southern was promoted to the position of Senior Analyst and Research

Officer in the Food and Drugs Division, a position which later became that of Second-in-charge of the Division and which he held at the time of his death on October 17th, 1960. In this latter position he retained an interest in agriculture and soils, but devoted his main attention to the determination of alcohol in blood and its interpretation in terms of intoxication. His service and experience in chemistry were recognized by his election as a Fellow of the Australian Chemical Institute in 1956.

Mr. Southern was for a long time a member of the Royal Society of Western Australia and an active participant in its affairs. He was Editor of the Society's Journal for 12 years (from 1930-31 to 1941-42) and has left abundant evidence of his industry and attention to detail.

6.—Copper, Molybdenum and Inorganic Sulphate Levels in Rottnest Plants

By S. Barker*

Manuscript received—16th February, 1960

Determinations of the copper, molybdenum and inorganic sulphate levels of plants from Rottnest Island, Western Australia, are reported. These analyses were undertaken during an investigation to determine whether the quokka, *Setonix brachyurus* (Quoy & Gaimard) population of the island suffers a seasonal copper deficiency.

Introduction

Shield (1959, p. 78) suggests that semi-starvation producing "a rather profound anaemia of the order of 25 per cent. decrease in the haemoglobin, red cell count, and haematocrit" is one of the principal causes of death in the Rottnest quokka, *Setonix brachyurus* (Quoy & Gaimard). Moir, Somers, Sharman and Waring (1954) and Moir, Somers and Waring (1956) have shown that the quokka has ruminant-like digestion, and this suggests that it, like the true ruminant, may show anaemia due to dietary deficiencies of "trace elements" such as cobalt and copper.

It has been shown in the sheep that: ingestion of inorganic sulphate increases the urinary excretion of molybdenum with a corresponding fall in blood molybdenum levels (Dick 1953a); high molybdenum and inorganic sulphate intakes for long periods exert a depressing effect on liver copper storage (Dick 1953b); experimental hypocuprosis can be produced by feeding intake levels of copper, molybdenum and inorganic sulphate similar to those occurring in pastures where grazing sheep develop hypocuprosis (Wynne and McClymont 1955).

Barker (1960) has shown that inorganic sulphate influences excretion of molybdenum in the urine, and blood molybdenum levels in the quokka. It has also been found in the quokka that the long term ingestion of raised intake levels of inorganic sulphate and molybdenum depresses liver copper storage (Barker, unpublished data). Thus it is possible that anaemia reported by Shield (1959) may be due in part to either direct or induced hypocuprosis.

The work required to test the thesis that copper deficiency causes a seasonal anaemia in the Rottnest quokka population is divided into four parts which are listed below:—

- (1) Determination of the copper, molybdenum and inorganic sulphate levels of food plants on Rottnest.
- (2) Quantitative determination of the various food plants constituting the diet of the quokka through the seasons.

From these data copper, molybdenum and inorganic sulphate intakes can be calculated.

- (3) Estimation of haematological values and blood copper and molybdenum levels throughout the seasons of the year.
- (4) Diagnoses of copper deficiency and the copper, molybdenum and inorganic sulphate levels at which an induced deficiency occurs.

The present paper gives the results of part (1) above. Part (2) is covered by work being carried out by G. M. Storr (Zoology Department, University of Western Australia) and will be reported elsewhere. The results obtained by the present author under parts (3) and (4) will be published later.

Methods

Determination of the precise composition of the diet (by plant species) is only possible by the methods of Storr [(2) above]. However, simple observation is sufficient to show that some plants are only eaten at certain seasons of the year while others are eaten over a more prolonged period. Furthermore a few plants which are heavily and persistently grazed, e.g. *Sporobolus*, are so restricted in their occurrence that it is inconceivable that they constitute a significant proportion of the diet of a large part of the population. These considerations were taken into account when plant samples were collected on ten occasions between December, 1957, and May, 1959, and only those portions of species actually being eaten at the time were collected.

Plants were collected by hand and placed in individual sample bags, and the bags were then tied inside a polythene sack. They were transported to the mainland laboratory on the afternoon of collection and were processed immediately. Gravimetric moisture determinations were made by weighing before and after heating in an oven at 100°C. for 24 hours. Dried samples were crushed in an all steel mill. For copper and molybdenum estimation, samples were wet digested in nitric, sulphuric and perchloric acids. Copper was estimated by the method of Eden and Green (1940) and molybdenum by the method of Piper and Beckworth (1948). Inorganic sulphate was estimated by the method of Dick and Bingley, the endpoint was determined by titration (Dick 1954).

Results

The mean results of copper, molybdenum and inorganic sulphate analyses and moisture determinations of plants collected at the West End

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and Lake Bagdad study areas between December, 1957, and June, 1959, are presented in Tables I and II.

The results of individual analyses carried out on two plant species are presented in Table III to show seasonal variation. The common "pigface" (*Carpobrotus*) is found in limited areas at West End and the "saltwater couch" (*Sporobolus*) on the edge of Lake Bagdad and at other lakes. Both plants are eaten extensively by the quokka.

Discussion

Bennetts and Beck (1942) listed copper levels of plants growing on copper deficient soils at Gingin. They considered that sheep would become deficient when grazing pastures containing less than 3.0 p.p.m. copper on a dry weight basis. They classified pastures containing 3.0 p.p.m. copper or less as deficient, 3.0 to 6.0 p.p.m. as marginal and more than 6.0 p.p.m. as normal. All levels were expressed on a dry weight basis. Using the classification of Bennetts and Beck, it is herein considered that on a sheep-basis

Rottnest plants are copper deficient. The only species analysed more than once that had consistently normal copper levels was *Eremophila glabra*. It seems likely that this species is a copper accumulator.

Plant molybdenum levels were low in both areas, but Lake Bagdad plant levels were higher than West End plant levels. There are no figures available for comparison from Western Australian mainland plants.

There are no published figures of inorganic sulphate levels in Australian plants. However, Beck (personal communication) has found that sheep pastures in Western Australia normally have inorganic sulphate levels ranging from 0.2 to 0.3%. In the present study mean inorganic sulphate levels in plants collected in the study areas were as high as 2% in some species. On a sheep-basis this level is high.

It can be seen from Table III that there is little change in copper, molybdenum and inorganic sulphate levels of *Carpobrotus* at different times of the year. The increase of copper and molybdenum levels in *Sporobolus* during

TABLE I

Copper, molybdenum and inorganic sulphate levels of plants collected from the Lake Bagdad area, Rottnest, between December, 1957, and May, 1959, expressed on a dry weight basis.

| Species | No. of samples | Moisture % | Cu p.p.m. | Mo p.p.m. | SO ₄ % |
|-----------------------------------|----------------|---------------|------------------|-------------------|-------------------|
| <i>Arthrocnemum halimifolium</i> | 10 | 83 (80-90) | 2.5 (1.1-5.1) | 0.6 (0.4-1.0) | 1.6 (0.9-2.3) |
| <i>Carex preissii</i> | 1 | 76 | 2.7 | 5.2 | 1.4 |
| <i>Ehrharta longiflora</i> | 3 | 81 (69-88) | 3.8 (2.4-4.9) | 5.4 (3.9-6.1) | 0.2 (0.1-0.2) |
| <i>Erythraea centaurium</i> | 1 | 79 | 8.0 | 2.6 | 0.4 |
| <i>Euphorbia peplos</i> | 1 | 85 | 2.4 | 3.6 | 0.5 |
| <i>Gahnia trifida</i> (leaves) | 8 | 35 (22-42) | 1.4 (0.6-1.9) | 0.6 (0.4-0.9) | 0.2 (0.2-0.3) |
| <i>Gahnia trifida</i> (seed head) | 1 | 48 | 2.4 | 0.3 | 0.1 |
| <i>Melaleuca pubescens</i> | 3 | 59 (56-61) | 2.4 (2.1-2.8) | 0.6 (0.5-0.8) | 0.81 (0.6-0.9) |
| <i>Rhagodia baccata</i> | 2 | 78 (74-83) | 1.5 (1.1-1.9) | 0.6 (0.4-0.9) | 0.5 (0.5) |
| <i>Salicornia australis</i> | 10 | 86 (79-90) | 2.3 (0.7-4.8) | 0.4 (0.2-0.7) | 0.9 (0.7-1.3) |
| <i>Samolus repens</i> | 3 | 62 (50-75) | 5.9 (5.8-6.0) | 3.4 (1.6-4.5) | 2.0 (1.8-2.3) |
| <i>Sarcocolla oleaceus</i> | 1 | 92 | 3.6 | 3.3 | 0.6 |
| <i>Solanum simile</i> (berries) | 5 | 70 (69-72) | 1.7 (1.4-2.0) | 0.9 (0.7-1.3) | 0.2 (0.1-0.3) |
| <i>Solanum simile</i> (leaves) | 1 | 81 | 2.3 | 3.6 | 1.0 |
| <i>Sporobolus virginicus</i> | 10 | 58 (50-75) | 3.9 (2.7-6.4) | 5.4 (1.9-16.6) | 1.0 (0.3-2.0) |
| <i>Stipa variabilis</i> | 2 | 48 (37-60) | 1.8 (1.3-2.4) | 3.1 (3.1-3.2) | 0.3 (0.3-0.4) |
| <i>Templetonia retusa</i> | 1 | 57 | 1.1 | 0.1 | 0.2 |
| <i>Threlkeldia diffusa</i> | 3 | 88 (83-92) | 2.8 (2.3-3.1) | 0.6 (0.5-0.8) | 0.5 (0.3-0.8) |
| <i>Valpia myuros</i> | 3 | 76 (69-82) | 4.4 (3.3-6.6) | 3.5 (1.7-4.7) | 0.3 (0.2-0.5) |

TABLE II

Copper, molybdenum and inorganic sulphate levels of plants collected from the West End area, Rottnest, between December, 1957, and May, 1959, expressed on a dry weight basis.

| Species | No. of samples | Moisture % | Cu p.p.m. | Mo p.p.m. | SO ₄ % |
|---|----------------|---------------|-------------------|------------------|-------------------|
| <i>Acacia rostellifera</i> (bark) | 1 | 49 (39-57) | 1.7 (1.2-2.2) | 0.9 (0.5-1.2) | 1.7 (1.5-1.8) |
| <i>Acacia rostellifera</i> (leaves) | 4 | 69 (66-77) | 1.4 (1.0-1.9) | 0.5 (0.1-1.0) | 1.0 (0.8-1.3) |
| <i>Atriplex cinerea</i> | 2 | 79 (72-86) | 1.8 (1.2-2.4) | 0.5 (0.3-0.7) | 1.0 (0.8-1.3) |
| <i>Bromus gussonei</i> | 1 | 87 | 9.7 | 0.3 | 0.4 |
| <i>Carpobrotus acquilatus</i> | 10 | 90 (87-94) | 0.8 (0.4-1.9) | 0.1 (0.0-0.2) | 0.4 (0.2-0.6) |
| <i>Enchylaena tomentosa</i> | 2 | 82 (75-90) | 4.1 (4.0-4.1) | 0.1 (0.3-0.5) | 1.2 (0.9-1.4) |
| <i>Eremophila glabra</i> | 4 | 73 (66-80) | 7.8 (4.7-11.5) | 0.5 (0.1-1.1) | 0.7 (0.5-0.9) |
| <i>Euphorbia peplus</i> | 1 | 93 | 3.8 | 1.2 | 0.5 |
| <i>Frankenia pauciflora</i> | 4 | 41 (34-56) | 2.3 (1.1-2.9) | 0.3 (0.3-0.4) | 1.8 (1.4-2.0) |
| <i>Melilotus indica</i> | 1 | 80 | 5.0 | 0.1 | 0.4 |
| <i>Nitraria schoberi</i> | 2 | 84 (79-89) | 1.2 (0.7-1.7) | 0.2 (0.1-0.3) | 0.6 (0.4-0.7) |
| <i>Oleacia axillaris</i> | 1 | 58 | 2.1 | 0.5 | 0.2 |
| <i>Poa australis</i> | 1 | 61 | 2.4 | 1.8 | 0.4 |
| <i>Rhatgodia laevata</i> | 9 | 82 (75-89) | 1.3 (0.5-2.7) | 0.4 (0.1-0.5) | 0.8 (0.5-1.2) |
| <i>Scaevola crassifolia</i> (bark) | 3 | 44 (42-47) | 3.6 (2.5-4.9) | 0.2 (0.1-0.3) | 1.3 (0.9-1.8) |
| <i>Scaevola crassifolia</i> (leaves) | 7 | 75 (71-83) | 2.8 (1.9-3.7) | 0.5 (0.3-0.6) | 1.4 (1.1-1.8) |
| <i>Solanum simile</i> (berries) | 1 | 72 | 1.4 | 0.8 | 0.2 |
| <i>Solanum simile</i> (leaves) | 1 | 78 | 1.6 | 2.3 | 1.6 |
| <i>Stipa radiabilis</i> | 4 | 46 (31-64) | 1.7 (1.1-2.2) | 0.7 (0.6-0.7) | 0.3 (0.2-0.6) |
| <i>Tetragonia implexicoma</i> | 7 | 85 (74-92) | 1.9 (0.9-2.9) | 0.1 (0.0-0.2) | 2.2 (0.4-3.8) |
| <i>Threlkeldia diffusa</i> | 3 | 81 (78-85) | 1.3 (1.1-1.5) | 0.3 (0.3-0.4) | 0.6 (0.5-0.7) |
| <i>Westringia douglasii</i> | 1 | 49 | 1.1 | 9.1 | 0.1 |

the summer months is possibly caused by faecal contamination from the increased number of animals which graze on the plant at this time of the year.

It will not be possible to calculate seasonal changes in trace element intake levels of quokkas on Rottnest until intake of the various plant species has been estimated quantitatively. However, the results of field and laboratory experiments show that quokkas in the Lake Bagdad area exhibit a seasonal anaemia associated with copper depletion, those living at West End do not (Barker, unpublished data).

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TABLE III

Seasonal changes in the moisture, copper, molybdenum, and inorganic sulphate levels of a grass (*Sporobolus*) collected at Lake Bagdad, and a succulent (*Carpobrotus*) collected at West End.

| DATE COLLECTED | <i>Carpobrotus aciculatus</i> | | | | <i>Sporobolus virginicus</i> | | | |
|----------------|-------------------------------|--------------|--------------|----------------------|------------------------------|--------------|--------------|----------------------|
| | Moisture % | Cu p.p.m. | Mo p.p.m. | SO ₄ % | Moisture % | Cu p.p.m. | Mo p.p.m. | SO ₄ % |
| 23/12/57 | 90 | 0.9 | 0.2 | 0.5 | 53 | 2.7 | 3.9 | 2.0 |
| 18/1/58 | 88 | 0.7 | 0.0 | 0.5 | 57 | 3.3 | 4.6 | 1.7 |
| 25/2/58 | 89 | 0.6 | 0.1 | 0.5 | 57 | 6.0 | 8.1 | 1.3 |
| 14/4/58 | 86 | 0.8 | 0.1 | 0.6 | 51 | 3.3 | 5.0 | 0.8 |
| 26/5/58 | 89 | 0.6 | 0.0 | 0.4 | 50 | 3.5 | 3.4 | 0.6 |
| 22/6/58 | 94 | 0.8 | 0.1 | 0.2 | 60 | 4.4 | 2.9 | 0.4 |
| 5/8/58 | 93 | 0.8 | 0.2 | 0.2 | .... | .... | .... | .... |
| 22/10/58 | 92 | 1.9 | 0.2 | 0.4 | 75 | 6.4 | 1.9 | 0.7 |
| 5/12/58 | 89 | 0.7 | 0.2 | 0.4 | 53 | 3.0 | 16.6 | 1.5 |
| 23/2/59 | 87 | 0.4 | 0.2 | 0.2 | 62 | 2.7 | 5.2 | 0.3 |
| 3/6/59 | .. | .... | .... | .... | 62 | 4.2 | 2.8 | 0.4 |

7.—The Cheek-teeth of *Hypsiprymnodon moschatus* Ramsay 1876 (Macropodidae: Marsupialia)

By W. D. L. Ride*

Manuscript received—20th September, 1960

The morphology of the cheek-teeth and their replacement in *Hypsiprymnodon moschatus* is described. The cusps of the unworn lower deciduous molariform premolar and the first molar indicate that the problem of cusp homologies of the lower molars of Macropodidae is more complex than originally believed. A better understanding of the homologies of the parts of the lophodont molars is achieved, e.g. the antero-basal-cingulum of some authors is the homologue of the basin of the trigonid.

Introduction

Hypsiprymnodon moschatus, the Musk-Kangaroo of Queensland, is the smallest of the Macropodidae and is also in some respects the most primitive of them. In spite of the phylogenetic interest which is attached to it, the implications to be derived from the morphology of its deciduous teeth are not understood.

In the collection of the National Museum of Victoria, Melbourne, there is an extremely fine but small series of skulls of this species which illustrates dental replacement. This series is described here. From it, it is established that the third premolars are fully sectorial teeth which only differ from the fourth premolars in size and in the number of transverse ridges which are on them. In this respect *Hypsiprymnodon* is not transitional between Phalangeridae and Macropodidae. However, the deciduous premolars (milk-molars) are less molarised than in other Macropodidae (except *Potorous* and *Atyops*) and throw much light on the cusp homologies of the succeeding molars. The structure of the maxillary teeth of *H. moschatus* also appears to lend support to Butler's theory of the action of gradient fields along the length of the developing tooth row.

Material

N.M.V. No. R4598 (Fig. 1a; Fig. 2a; Plate 1, Figs. 1 & 2) ♀ Locality, date of collection, and collector unknown. General description: Juvenile with third premolar fully erupted, succeeded by maxillary teeth to the second molar which is only just visible. The second upper incisor is fully erupted, while the first and third upper incisors and the canines are only partly erupted.

N.M.V. No. R5449 (Fig. 1b; Fig. 2b; Plate 1, Fig. 3) Sex unknown. Locality—Evelyn Scrub, North Queensland. Date of collection unknown. General

description: The permanent premolar has replaced the milk-molar but the third premolar in front of it is still in position.

N.M.V. No. R4697 Adult ♀ from Lake Eacham, North Queensland, 2,300 feet, 21.5.11. Collector "G.S." General description: Teeth fully erupted but relatively unworn.

Description

Maxillary Teeth

R.4598. (Fig. 1a; Plate 1, Fig. 1)

P³. The third upper premolar is a specialised sectorial tooth with a longitudinal median ridge which forms its cutting edge. The front of the tooth is slightly tilted outwards so that the axis of this ridge is at a small angle to the main longitudinal axis of the molar toothrow. Five transverse crests cross this ridge and, at the points where they do so, the ridge is raised into cusps so that the cutting edge of the tooth is serrated. The tooth appears to be three-rooted. dP¹. The milk-molar (or deciduous fourth premolar) has three main cusps. The main longitudinal axis of the tooth is marked by a continuous longitudinal crest which is made up of the antero-posterior ridges of the two main cusps of the tooth which are thus united. The longitudinal crest is not functionally continuous with that of P³ in front of it, but it is slightly displaced buccalwards. However, that part of the crest closest to P³ (the median anterior ridge of the paracone) is parallel to the longitudinal crest of P³. At the front of dP¹ this crest bifurcates and is continued back along both sides of the tooth as a cingulum. On the lingual surface the cingulum is well-marked, cuspidate, and finally becomes continuous once more with the posterior end of the main longitudinal crest (the median posterior ridge of the metacone). On the buccal surface of the tooth, the cingulum is less well-marked and, posterior to the level of the paracone, it is no longer visible. The main cusps are well-marked. The paracone, which rises very close to the centre of the tooth, forms the highest part of the median longitudinal crest. The metacone lies behind it, close to the posterior edge of the tooth and, strangely, it appears to lie slightly to the lingual side of the median longitudinal crest so that there is a distinct kink in the ridge where it turns to ascend to the tip of the cusp. The protocone is a distinct cusp situated about midway along the lingual cingulum; there is a small cingular cuspsule anterior to this, and

Western Australian Museum, Perth, Western Australia.

in front of this cuspule the cingulum becomes functionally continuous with the median longitudinal crest of P^3 . Behind the protocone there is a well-marked cingular cusp mesial to the metacone. This is almost certainly the hypocone.

M^1 . The first molar is quadritubercular and, unlike the condition in the tooth in front of it, the four major cusps form two more-or-less parallel longitudinal crests of equal (but not constant) height. The lingual one is functionally continuous with the posterior part of the lingual cingulum of dP^1 , and is clearly its homologue, while the buccal one is functionally continuous with the median longitudinal crest of dP^1 . The tooth, in comparison to dP^1 , is shortened in front of the paracone; this gives it a rather oblong shape. M^1 has all the cusps of dP^1 , but their size relations are different—in addition one new cusp has appeared. This new cusp is on the anterior ridge of the paracone where it sweeps down to become continuous with the cingulum. As in dP^1 , the lingual cingulum is continuous but on it the protocone and hypocone are so enlarged that it is as high as the other longitudinal crest which lies buccal to it; the hypocone is even higher than the metacone which lies lateral to it. As in dP^1 , the metacone is clearly set off from the longitudinal crest and is connected with it by a slight transverse ridge.

M^2 . In this specimen the second molar is just visible in its alveolus and it appears to be very much like M^1 . The main differences are that the cingular cuspule on the anterior slope of the protocone is not present, and that the apex

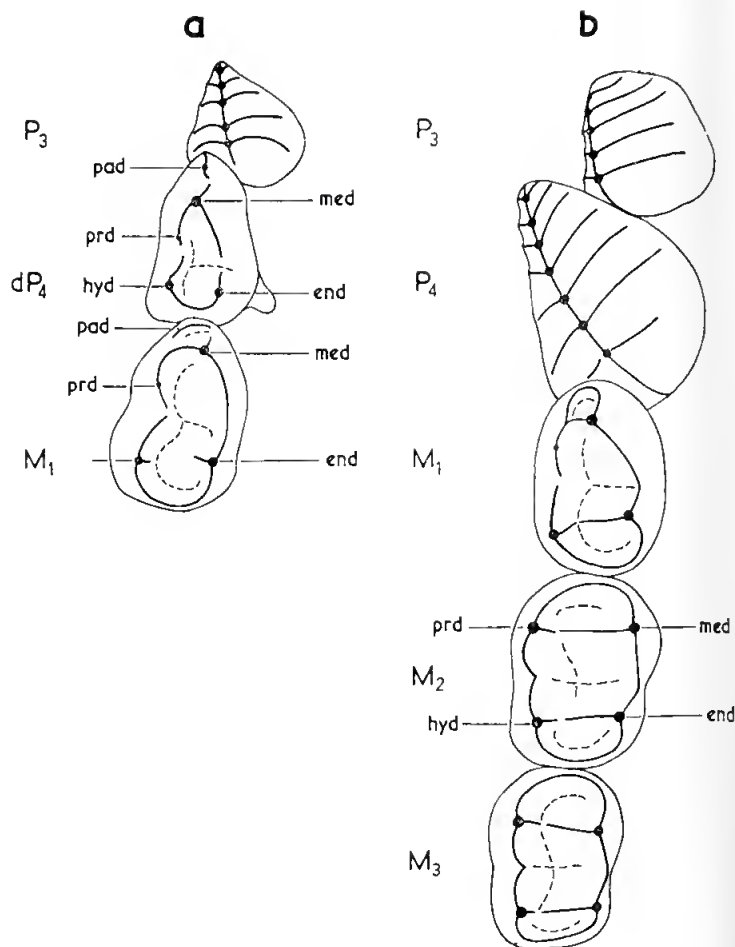


Fig. 2.—Mandibular tooth-rows of *Hypsiprymnodon moschatus* (a) R4598, right row reversed, (b) R5449, left row. Unerupted teeth not shown. Buccal side towards the left of the page. Abbreviations: prd, protocone, med, metacone, pad, paracone, hyd, hypocone, end, entocone. Ridges and crests shown by continuous lines, bottoms of valleys by broken lines.

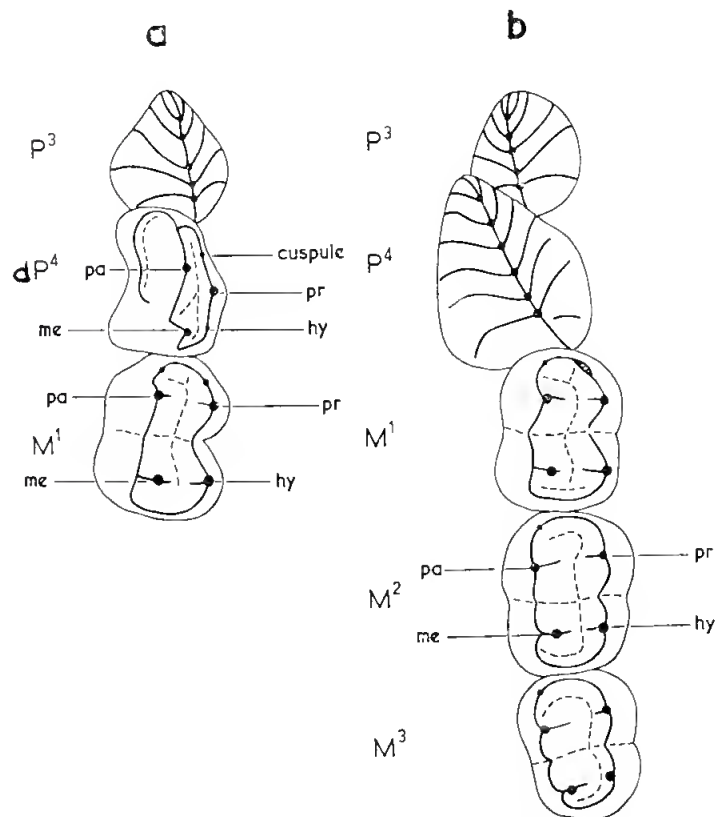


Fig. 1.—Right maxillary tooth-rows of *Hypsiprymnodon moschatus* (a) R4598, (b) R5449. Unerupted teeth not shown. Buccal side towards the left of the page. Abbreviations: pa, paracone, me, metacone, pr, protocone, hy, hypocone. Ridges and crests shown by continuous lines, bottom of valleys by broken lines.

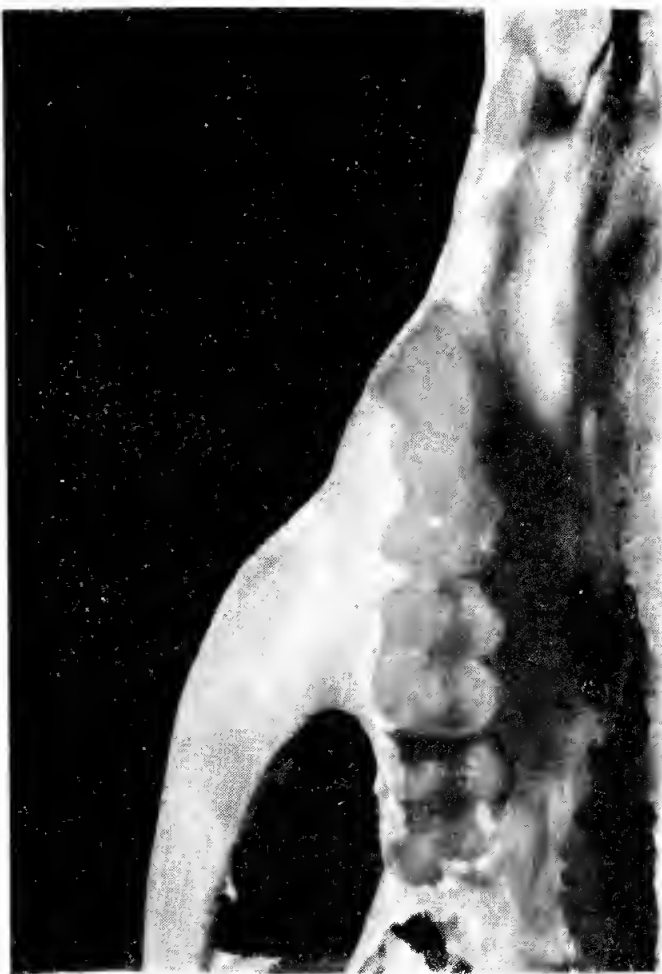
of the paracone (rather like that of the metacone) is also slightly set off to the lingual side of the buccal longitudinal crest.

R.5449. (Fig. 1b.)

In this specimen P^1 has replaced dP^1 but P^2 has not been shed. P^3 is in all respects similar to that described in R4598.

P^1 . This sectorial is larger than P^3 and the angle between its median longitudinal crest and the main axis of the tooth-row is greater (i.e. it is more sharply out-turned). Further, six transverse crests cross the longitudinal crest instead of five. On the postero-lingual surface of the tooth a seventh ridge runs up to the median longitudinal crest but fades away before it reaches it. It would appear to be directed to a point slightly to the rear of the cuspule formed where the sixth transverse ridge and the longitudinal ridge intersect.

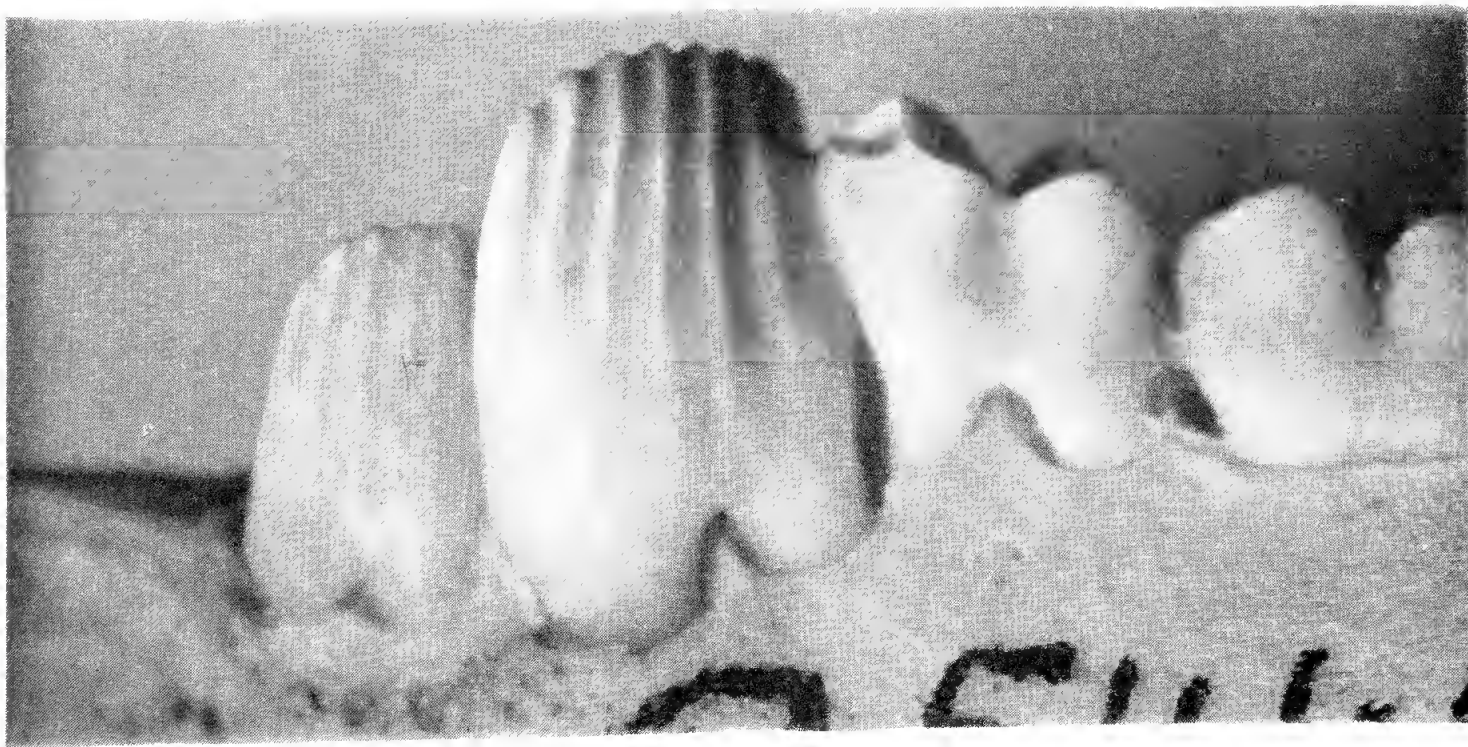
M^1 . In this specimen (in which tooth replacement has taken place) it is now clear that the small cingular cuspule anterior to the protocone is functionally related to the median longitudinal crest of P^1 in the same way as its homologue in dP^1 is to the median crest of P^3 . In this specimen the cuspule has already become worn and is scarcely discernible on the anterolingual slope of the protocone; a well-marked wear-facet almost obliterates it. This facet also runs on to the posterolingual face of P^1 .



1



2



3

PLATE I

Fig. 1.—Right maxilla of R4598.

Fig. 2.—Mandibular tooth-rows of R4598. Left M² exposed in alveolus, undissected on right. The thin bone at the posterior end of the mandibular symphysis has broken away exposing the root of the developing incisor.

Fig. 3.—Left lower premolars of R5449. P₃ and P₄ are both in place and are morphologically similar. Photograph taken of buccal surface.

M²M³. These teeth are essentially similar to M¹ except that the cingular cuspule anterior to the protocone is not present. There are also changes in the relative sizes of the cusps from M¹ to M³. These changes mainly involve the small cuspule anterior to the paracone, and the metacone, which both become progressively reduced, and the protocone which becomes progressively larger.

R4697. In this specimen P³ has been shed. P¹ is in place and all molars are fully erupted. The posterior molars are only slightly worn. P¹ and M¹⁻³ add nothing further to the foregoing descriptions.

M⁴. In the last molar the metacone is very small indeed being little more than a raised cuspule on the posterior crest of the paracone where it sweeps round to become the posterior cingulum. The trend in the reduction of the cuspule anterior to the paracone which has been described in M¹⁻³ has stopped and it even appears to be slightly larger than that of M³, it appears to be anterobuccally displaced. The main cusp of the tooth is clearly the protocone. The tooth is essentially tricuspid the main cusps being the paracone, the protocone, and the hypocone.

Mandibular Teeth

R4598 (Fig. 2a; Plate 1, Fig. 2)

P₃. The cusp pattern of the third lower premolar is the same as that of its upper homologue. There is a similar longitudinal crest with five transverse crests; there are raised cusps where these intersect.

dP₄. The lower milk-molar is a tooth which is shaped like a wedge with the apex directed anteriorly. The trigonid is compressed. Its main cutting crest runs obliquely from the anterior-buccal-face to the lingual surface of the tooth which it reaches before the commencement of the talonid. This crest is parallel with that of P₃ but is not functionally continuous with it. The metaconid is by far the largest cusp of the tooth and is the main contributor to the functional crest. The paraconid is a small but distinct cuspule on the antero-buccal slope of the ridge of the metaconid. From the buccal side of the apex of the metaconid a small crest descends and sweeps backwards as far as the buccal edge of the valley which runs transversely across the tooth between the trigonid and talonid. Just before this small crest reaches the bottom of the valley, it is interrupted by a raised cuspule. This is clearly the protoconid since it only differs in size from that cusp on the succeeding tooth (and the protoconid of M₂₋₄ of other specimens). The talonid has a marginal crest which is slightly raised into cusps in two places. One of these elevated cusps is buccal (the hypoconid) and the other lingual (the entoconid).

M₁. The talonid of the first lower molar is considerably enlarged and its cusps are widely separate as compared with those of dP₄. The trigonid is about the same size as that of dP₄, but the posterior part of the tooth is so much larger that the anterior part of the trigonid appears minute by comparison. The valley between paraconid and metaconid is deepened

and broadened behind the laterally-widened paraconid; this transversely placed cusp and the valley behind it thus appear as a small fossette anterior to the metaconid. The ridge which bears the protoconid is much more distinct than it was in dP₄ but the protoconid is still little more than an eminence which is raised slightly above it. The two cusps of the talonid stand well above the general level of its marginal crest and are both nearly as high as the metaconid which is no longer the only really large cusp as it was in dP₄. From both the entoconid and the hypoconid, low ridges run transversely down into the basin of the talonid.

M₂. In this specimen the second lower molar is scarcely visible in its alveolus and, from what can be seen, it appears that the protoconid, paraconid, hypoconid, and entoconid are more-or-less equal in height and are set opposite each other so that the tooth is oblong in shape.

R5449. (Fig. 2b; Plate 1, Fig. 3.)

In the mandible of this specimen, as in the maxilla, the permanent premolar has replaced its milk predecessor. Here, too, the third premolar is still in position.

P₃. Is identical with that of specimen No. R4598.

P₄. Here as in the upper permanent premolar, there are seven transverse ridges but the seventh is rather better developed so that it reaches and crosses the longitudinal crest. As in the case of the other six, there is a small cuspule at the point at which they intersect.

M₁. The first lower molar is like that already described for R4598, but there is a somewhat greater development of the ridge which runs away from the apex of the entoconid towards the hypoconid. In the centre of the basin of the talonid this meets a similarly developed ridge from the hypoconid. This transverse crest cuts off the posterior part of the basin of the talonid from the median longitudinal valley of the tooth so that a small posterior fossa is formed at the back of it. This is bounded posteriorly by the marginal crest which runs round the back of the tooth between hypoconid and entoconid (see description of dP₄ in R4598).

M₂. In the second lower molar, the protoconid is as high as the entoconid and the hypoconid; further, it is displaced buccalwards so that there is now a wide space between it and the metaconid. It will be remembered that in dP₄ the protoconid is little more than an elevation on a crest which swept around the front of the tooth, first buccalwards, then posteriorly from the tip of the metaconid. In M₂ the crest still remains but it has here become greatly depressed between protoconid and metaconid so that it is now made up of two separate ridges which meet in the bottom of the median valley of the tooth. These crests run transversely from the apices of their respective cusps (protoconid and metaconid) down into the median longitudinal valley. This valley runs antero-posteriorly down the centre of the tooth and is only broken where the transverse ridges from the protoconid and the metaconid, and from hypoconid and entoconid, meet. The paraconid has now disappeared and the

ridge, which in dP_4 was the anterobuccal ridge, now sweeps down from the metaconid around the front of the tooth and up to the apex of the protoconid. The tooth is now a typical macropod molar with two transverse lophs (here somewhat depressed between the cusps) and an anterior "shelf," or "anterior basal cingulum" (actually the basin of the trigonid with the paraconid depressed) and a "posterior fossa" (actually the cut-off posterior part of the basin of the talonid).

M_3 . The third molar is smaller than the second but otherwise not different in form from it.

M_4 . This tooth is just visible in its alveolus. R4677.

M_4 . The last lower molar is smaller than M_3 but is otherwise morphologically similar to it.

Discussion

Maxillary Teeth

This small but excellent series of *Hypsiprymnodon* establishes that the third and fourth premolars are both more highly specialized as sectorials than those of most other Macropodidae. Like *Bettongia*, P^3 is as specialized as P^4 and only differs from it in its rather smaller size and less number of grooves. Some species somewhat closely related to *Bettongia*, e.g. *P. platyops*, are much less specialized in this respect, as was the specimen of *Hypsiprymnodon* figured by Carlsson (1915, Plate 2, Figs. 12-15), where P^3 is shown to be a five cusped tooth without the extreme sectorial specialization of P^4 . Tate (1948, p. 244) made Carlsson's statement the basis of his remark that the difference between P^3 and P^4 of *Hypsiprymnodon* is greater than in all Macropodidae. In my discussion of the form of the cheek-tooth row in Macropodidae (Ride 1956, p. 423) I drew attention to Carlsson's description and stated that *Hypsiprymnodon* was an exception (and by inference more primitive) to the general rule that macropods possess, at all stages of growth, a row of cheek-teeth which comprises a sectorial premolar followed by molariform teeth (i.e. P_3 sectorial, dP_4 molariform, M_1-4 molariform or P_4 sectorial, M_1-4

molariform). Some species depart from this in late life when anterior teeth have become shed and the sectorial lost.

Wood (1960), in a paper received while this paper was in press, has shown that P^3 of *Hypsiprymnodon* is sectorial as in other Macropodidae and that Carlsson had mistaken dP^4 and M^1 for P^3 and dP^4 .

In the single specimen of *Hypsiprymnodon* in the N.M.V. series which shows the process of tooth replacement (R5449) it is seen to be atypical of Macropodidae since only dP^4 is replaced. P^3 is presumably shed later. Wood (1960) found this in his material.

Although both permanent premolars (P^3 and P^4) are more specialized than those of most other Macropodidae, the milk-molar (or deciduous premolar) dP^4 is less molariform than that of all other genera of this family known to me, with the possible exception of some *Potorous*. The only skull of *Potorous platyops* in the collection of the Western Australian Museum has a worn dP^4 which appears to indicate that this species may be as unspecialized as *H. moschatus* in this respect.

Butler (1952b) has applied the theory of gradient fields to the development of the dental lamina in an attempt to understand the phenomenon of the progressive molarisation of milk molars which is so common a feature of the phylogeny of herbivorous mammals. He has argued (1952b, p. 838) that molarisation of the milk molars may be regarded as an extension forward in the dentition of the sphere of action of the ontogenetic factors that cause the dental rudiments to develop into molariform teeth. He suggested that, primitively, the molarising factors at the milk-molar level become modified before the ontogenetically-later permanent premolars develop. Thus permanent premolars appear as simplified (unmolarised) replacements of molariform teeth. However, in forms that are evolutionarily advanced in the development of molariform tooth-rows the action of molarising factors persists longer in the premolar region with the result that the permanent premolars also became molarised. Butler (1952b, p. 819) has pointed out premolars may be

TABLE I

Lengths of upper premolars of *Hypsiprymnodon moschatus* and relation between growth of the molar-row and premolar replacement.*

| Number | N.M.V. R4598 | N.M.V. R5449 | N.M.V. R4697 | N.M.V. R4597 |
|--|----------------------|---------------------|------------------------------|----------------------------|
| Sex | ♀ | ? | ♀ | ? |
| P^3 | 2.5 | 2.4 | ... | ... |
| dP^4 | 2.9 | ... | ... | ... |
| P^4 | ... | 4.0 | 4.2 | 4.0 |
| Stage of molar eruption | M^1 fully erupted | M^3 fully erupted | M^4 fully erupted (unworn) | M^4 fully erupted (worn) |
| Point in molar row opposite descending processes of zygomata | M^1 posterior loph | $M^{1/2}$ contact | $M^{1/2}$ contact | M^3 middle of tooth |

* Crania were incomplete and basal length cannot be given. Teeth were measured along the major axis of each tooth and only enamel surfaces were included.

simpler in pattern than the deciduous teeth which they replace (hyposphyric) or they may even have the same patterns (isosphyric). He has shown that in the marsupial *Didelphis* the replacing premolar is hyposphyric (Butler 1939) and, in terms of molarizing factors and gradient fields in the developing dental lamina, that P^1 represents a much lower level on the molarization gradient than its ontogenetic predecessor (heteroclinous). However, in *Hypsiprymnodon* and other Macropodidae the permanent premolars P^3 and P^4 are so unlike the milk-molar (dP^4) that additional modifying factors are clearly operating.

Sectorial premolars are developed in Phalangerinae (the group from which the Macropodidae are presumed to have evolved) but little is known of tooth replacement in them. In juvenile *Trichosurus vulpecula* P^3 is absent and only dP^4 is replaced by P^4 . P^4 is a sectorial while dP^4 is a bicuspid, i.e. the molarization gradient has not reached dP^4 .

Several groups of Phalangeridae have developed sectorials independently. In each of them the specialisation appears to be confined to the last premolar (P^4) while P^3 may be widely different from it or even absent. In the fossil form *Burramys parvus* the last premolar (P^4) is a serrated sectorial which is scarcely different from that of *Hypsiprymnodon moschatus* while P^3 is a small buttress-like nubbin (without cusps) which lies adpressed against its antero-lingual face (see Ride 1956). It would seem that nowhere among known Phalangeridae is there evidence of a gradient field of sectorial elaboration from the front to the rear of the tooth-row.

Bensley (1903, p. 147) recognised the probability that the evolution of sectorial premolars in Macropodidae was one of forward elaboration from the last permanent premolar (P^4). From the morphology of P^3 of *Hypsiprymnodon* it is now clear that *Hypsiprymnodon* is far from primitive in this respect; indeed, it is as specialized as *Bettongia*. This conclusion serves to emphasize the anomalous phylogenetic position of *Hypsiprymnodon*. It has been considered by many to be the most primitive of all Macropodidae and this is clearly true of some characters which it possesses, e.g. the hallux, digital pads in the pes, simple stomach, simple molars, scarcely molarized dP^4 . In other directions however, it is clearly specialized to a greater extent than most Macropodinae e.g. possession of anterior-vaginal-expansions in the female urogenital system (see Pearson 1945, 1949a & 1949b), the degree of elaboration of P^3 , and the contact between squamosal and frontal in the side of the braincase.

This study of cusps of the upper molars of *Hypsiprymnodon* supports the nomenclature which is conventionally applied to them in Macropodidae. In the milk-molar (dP^4) the paracone is the largest cusp and it can be serially traced down the molar series as the antero-external cusp. Further, it is likely that this is the primary cusp (see Butler 1956). The protocone and metacone are developed on the lingual cingulum. This supports Butler's (1941) contention that the protocone on the

molariform teeth is serially homologous with the lingual cingulum of less molariform teeth.

A comparison of molar cusps from dP^4 backwards also adds probability to the hypothesis of the action of gradient fields in dental ontogeny. It seems that such features as the graded increase in size of the protocone from anterior to posterior teeth, and similar increase in size of the metacone to M^1 and then its subsequent reversion to small size in M^4 can best be explained in this way. There is, however, one cuspule on two of the upper teeth which can best be explained by means other than the operation of gradients. This is the cuspule on the anterior slope of the protocone dP^1 and M^1 . In both teeth this cuspule is related in position to the functional cutting edge of the tooth in front of it in such a way as to provide continuity between the teeth. In the case of M^1 the cuspule is related both to the lingual cingulum of dP^4 (Fig. 1a) and to the median longitudinal crest of dP^4 (Fig. 1b), although in the latter case the function does not persist long since its place is soon taken by a wear facet. It is of interest to compare this cuspule with those of *Burramys parvus* in which P^4 is similarly outwardly rotated and with *Dactylopsila trivirgata* in which the axis of P^4 is rotated in the opposite direction. In *Burramys parvus*, M^1 has a cuspule which is identical in position with that of *Hypsiprymnodon*, while in *Dactylopsila* an accessory cuspule is developed anterior to the paracone (see Ride 1956, p. 426 and Fig. 3). The development of these cuspules would appear to be related in some way to the shearing function of the crest of the tooth in front. Butler (1952a, p. 786, Fig. 5) illustrates parastyles on the milk-molars of Tapiroidea which are almost certainly of the same kind. Here, however, one can also discern a gradient of elaboration along the tooth-row much as the one that can be seen in the small cuspules on the anterior ridge of the paracone of the molars of *Hypsiprymnodon*.

Mandibular Teeth

The morphology of the lower molars and milk-molar of *H. moschatus* clearly supports the cusp-terminologies in use in the modern literature of the Phalangerioidea (e.g. Stirton 1957). Bensley (1903) appears to apply the same terminology to the posterior molars of Phalangerinae, Phascolarctinae and Macropodidae, but his reason for this is not clear since in his discussion of the morphology of M_1 of the Macropodidae he argues that the element which I consider to be a protoconid is actually a "protoconid-like" accessory cusp and my metaconid is actually the true protoconid. In particular, he states with reference to the potorines *Bettongia* and *Aepyprymnus* (op. cit. p. 145) that the anterior lobe of M_1 "bears an accessory cusp on its outer slope. The new cusp takes up the position of a protoconid, but is obviously not homologous with that element, the true protoconid being the inner cusp, the true metaconid having been lost in the Phalangerine stage". If this view is correct, and if

the four cusps of M_1 are the serial homologues of those of the teeth behind, then a new cusp terminology (different from that used by all present workers) is necessary for the posterior molars of Macropodidae. The alternative is to assume that dP_4 and M_1 have special patterns resulting from occlusal relations with P^3 and P^4 and that the positions of the "new" cusps which have developed on them are merely coincidentally those occupied by their non-homologues on M_{2-1} . The strongest argument in favour of this view is that the principal cusp of the lower teeth is the protoconid and it is surprising to find it reduced in the least molarized of the cheek teeth although such an occurrence might be expected further up the molar gradient.

This problem of interpretation of the homology of the cusps does not arise among Phalangerinae. When a reduction in the number of cusps of M_1 occurs (as it does in *Petaurus breviceps*), the two posterior cusps are clearly the entoconid and hypoconid, while the anterior cusp would appear (by comparison with M_2) to be the homologue of the antero-lingual cusp of the quadritubercular tooth, i.e. the metaconid. However, in less-specialized Phalangerinae (e.g. *Trichosurus vulpecula*) M_1 is quadritubercular and the cusp which is missing on that tooth in *Petaurus* is present although somewhat reduced. The reduced cusp is the metaconid and the larger protoconid stands close to it, being somewhat lingually displaced, so that the isolated anterolingual cusp of *Petaurus* is clearly the protoconid in spite of its apparent correspondence with the metaconid of the succeeding tooth.

In the Phascolarctinae, a problem of interpretation like that in *Hypsiprymnodon* occurs. In *Pseudocheirus* one of the anterior cusps of M_1 is reduced, and here I believe that it is the protoconid which is reduced while the metaconid is enlarged.

Bensley (1903, p. 137) interpreted the M_1 of Phascolarctinae and Phalangerinae as I have done but, in addition, he mentioned that an alternative interpretation would be to consider the antero-buccal cusp of the phascolarctine M_1 a new accessory cusp and the large antero-lingual cusp the true protoconid—the metaconid having disappeared. If this latter interpretation is correct, the protoconid would be the antero-lingual cusp of the phascolarctine M_1 ; again the succeeding lower molars have the same number of cusps in almost identical positions and these are also presumably the serial homologues of those of M_1 .

In conclusion, if the principle of the serial homology of cusps occupying similar positions on successive teeth in the molar row be accepted, then the logical outcome of these interpretations of M_1 (which differ from those employed in this paper) is that the protoconid of the succeeding molars is antero-buccal in Phalangerinae, while it is antero-lingual in Phascolarctinae and

Hypsiprymnodon (and presumably in all Macropodidae). Since Macropodidae are commonly held to be more closely related to Phalangerinae than to Phascolarctinae, this can only be regarded as unlikely.

From Bensley's account it is clear why he considered that evidence existed of the loss of the metaconid in primitive Macropodidae. In his description of the M_1 of *Hypsiprymnodon* (p. 144) he stated that "as in the advanced Phalangerinae, the first lower molar has but one cusp on its anterior lobe". Bensley clearly had no specimen of *Hypsiprymnodon* with dP_4 or with unworn M_1 and he did not observe the small protoconid.

There is no evidence that the first molar of Macropodidae has ever been other than four cusped, and there is certainly no evidence that the ancestral form possessed a three cusped tooth like that found in some small Phalangerinae today. The almost three cusped M_1 of *Hypsiprymnodon* is convergent upon that of *Petaurus* and similarity is achieved by the loss of different elements.

The condition of the partly molarised M_1 and dP_1 are of great help in understanding the homologies of the parts of the lophodont molars of more typical Macropodinae. From these it is clear that the so-called "antero-basal cingulum" of the macropodine lower molar is the homologue of the basin of the trigonid.

Acknowledgments

The specimens which I have described were lent to me through the courtesy of Mr. C. W. Brazenor, the Director of the National Museum of Victoria, and I am indebted to Dr. P. M. Butler for criticising the manuscript of this paper and for his valuable suggestions. However, it is only fair for me to say that the views which I express on the homologies of the cusps of the lower molars are my own.

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8.—Some Preliminary Experiments on Adrenal Function during Seasonal Stresses in a Wild Marsupial (*Setonix brachyurus*)

By E. H. Herrick*

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Introduction

An effort is being made by a group of workers in Western Australia to assess the clinical conditions of an island population of the herbivorous ruminant wallaby *Setonix brachyurus* during various seasons of the year (Main, Shield and Waring 1959; Hodgkin and Sheard 1959). On Rottnest Island the animal is protected by fauna laws and has no predators, so an excellent opportunity is presented for analysing causes of death and hence population control. Much work on the individual physiology of the animal has been carried out. It has been established, from skull and dentition data, that death occurs almost entirely in late summer. Analysis of the protein content of the diet gives a strong indication that the seasonal fall in plant protein in late summer is a major agent in precipitating death, but other aspects such as availability of free water, trace elements, etc. are under consideration. Whatever the primary cause of the general seasonal debility (and death of some individuals) there is little doubt that in late summer animals are exhibiting stress as envisaged in the Selye syndrome. Under these circumstances it is of interest to enquire how adrenal function varies at different seasons and this paper reports some preliminary experiments along these lines.

Analysis of adrenal steroids in the adrenal vein would clearly be the method of choice, but at present there is no way of doing this under field conditions. Roberts (1957) has shown that there is usually correspondence between ability of an extract to stain steroid secretions and to deplete ascorbic acid, but the correspondence is not precise. Nevertheless, a valuable indication of steroid secretion, in the absence of its direct measurement, can be obtained from measuring ascorbic acid content, which is practicable in the field. Therefore, ascorbic acids were measured. The fat content, histologically determined, was estimated to see if it correlated with the ascorbic acid content.

Materials and Procedure

Only females were used and they were selected for similarity of history—area where collected, length of time in captivity, care and feeding. They were weighed at the beginning of the experiment. Some animals were killed for use as normal controls. Others were kept with feed

(sheep nuts, 11% protein) but no water and then periodically animals were killed in varying stages of dehydration.

All animals were killed by cervical dislocation after which the adrenal glands were promptly removed. The glands were weighed individually to the nearest milligram with a torsion balance. The right one was used immediately for ascorbic acid determination and the left one was cut in two with one half being placed in Bouin's fixative for histological study and the other in 10% formalin for fat determination. The weights of liver, spleen, and in some cases of the empty stomach were recorded. The right adrenal gland was assayed for ascorbic acid content using the procedure described by Hawk, Oser and Summerson (1947, p. 1137). Readings were made with a Bausch and Lomb Spectronic 20 colorimeter. In retrospect it is realised that these should have been matched against weighed quantities of pure ascorbic acid to achieve a reference standard. This was not done but the figures afford a reliable comparative measure of the samples. The tissues placed in Bouin's fixative were sectioned and stained with Ehrlich's haematoxylin. Those fixed in formalin were sectioned on a freezing microtome and sections were stained with Sudan III and IV for fat determination.

Another phase of the study involved observations on animals from Rottnest Island which had not been in captivity previously. Groups of animals were collected from the "North Road" area where there was no known source of drinking water and are referred to here as the "Rottnest dry" animals. Others were collected from the "Serpentine" area where there were sources of drinking water and are known as "Rottnest wet" animals (map in Hodgkin and Sheard, 1959). All Rottnest animals were collected at night using hand nets and were held in bags until the following day. The processing of the animals was similar to that of the yard animals except that the right adrenal glands were placed in plastic vials and frozen in a thermos jar of dry ice (solid CO₂). Ascorbic acid determinations were made the following day.

In determining adrenal fat, sections of the cortex were, by observation, divided into four equal regions which were numbered from the outer to the inner zones (Fig. 1). Scores were assigned to each area from one to four upon the estimated density of the Sudan stain. The sum of these gave the "score" for that slide. Two separate slides, stained at different times, were evaluated and scores were compared. There was close agreement between the two slides.

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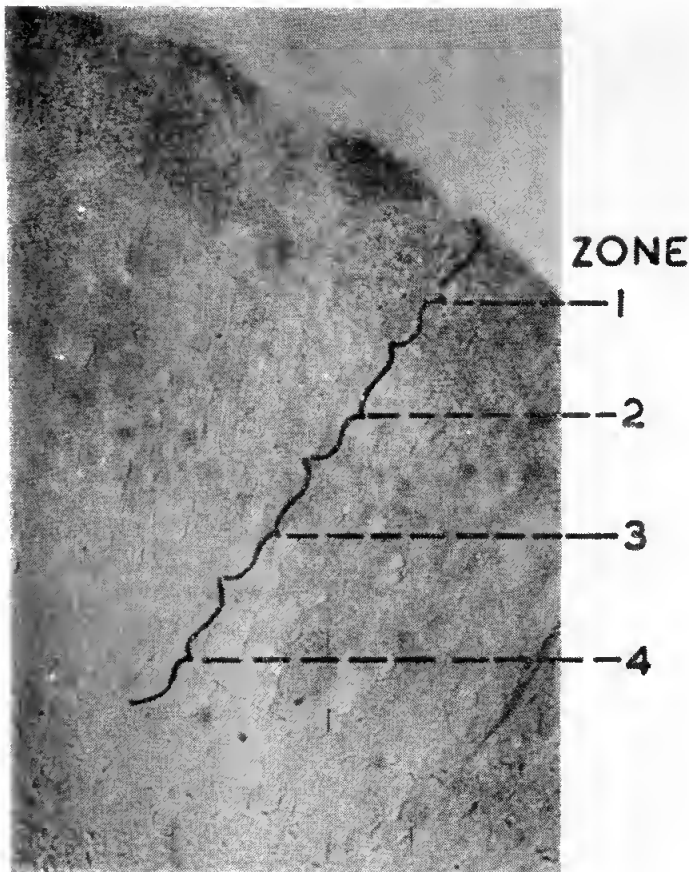


Fig. 1.—Photomicrographs of sections of adrenal glands with Sudan staining to show fat. Upper section with little fat giving a score of 2-1-1-0. Lower section with high fat with a score of 4-3-2-1.

Results

One group of nine quokkas was placed in a large yard without water but with limited green vegetation growing and with dry feed (sheep nuts) available. These animals had previously been confined to pens for several weeks with

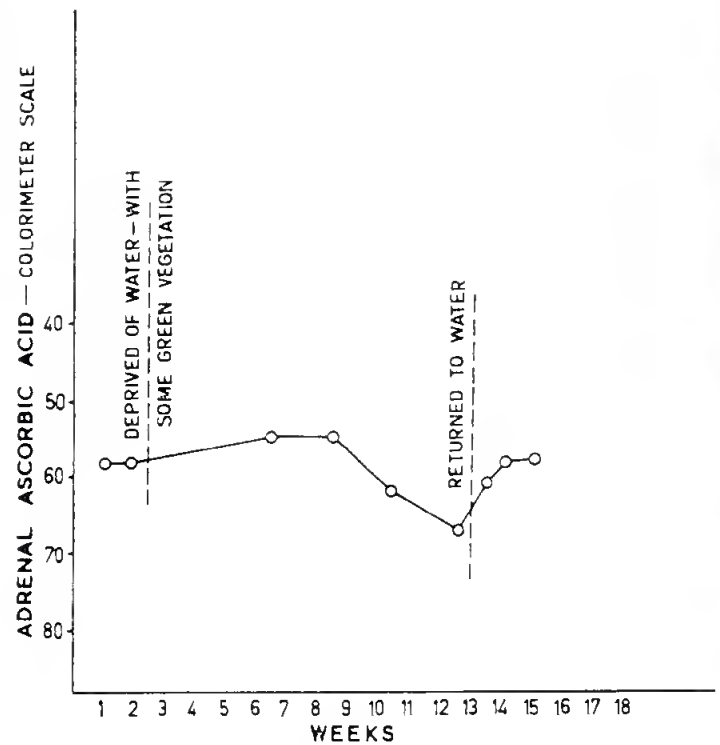


Fig. 2.—Levels of adrenal ascorbic acid in animals deprived of water. Some green vegetation was growing in pen for the first five to six week. After the 13th week, three animals were returned to water.

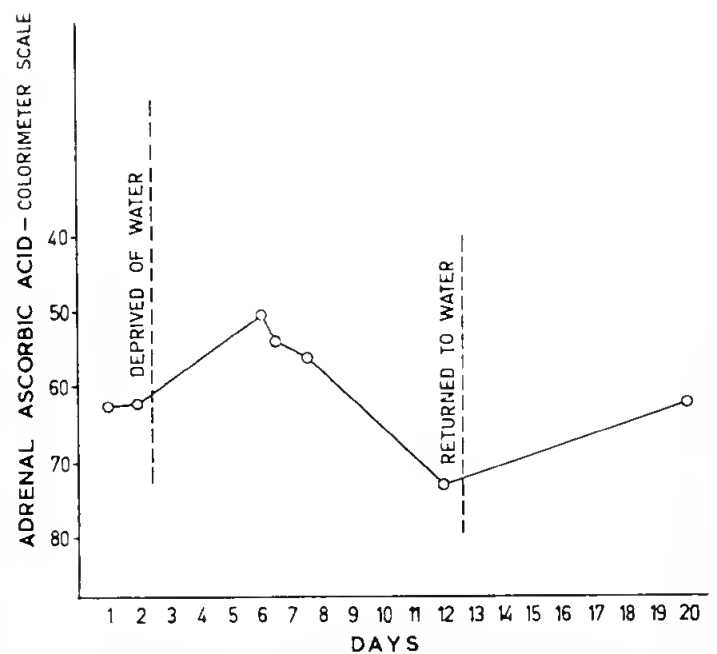


Fig. 3.—Levels of adrenal ascorbic acid in animals with conditions similar to those in Fig. 2 except no green feed was available from the start.

unlimited feed and water. Animals were killed at intervals. During the three to four weeks that some green vegetation was available, there was little loss of body weight. Results from adrenal ascorbic acid determinations indicated a rise in the earlier stages of dehydration when compared with animals receiving water. Following this initial rise the ascorbic acid level dropped and continued to do so as long as the animals survived without water. Three animals in the group were returned to feed and water after dehydration and within two weeks on full feed and water the ascorbic acid was determined to be at normal levels (Fig. 2).

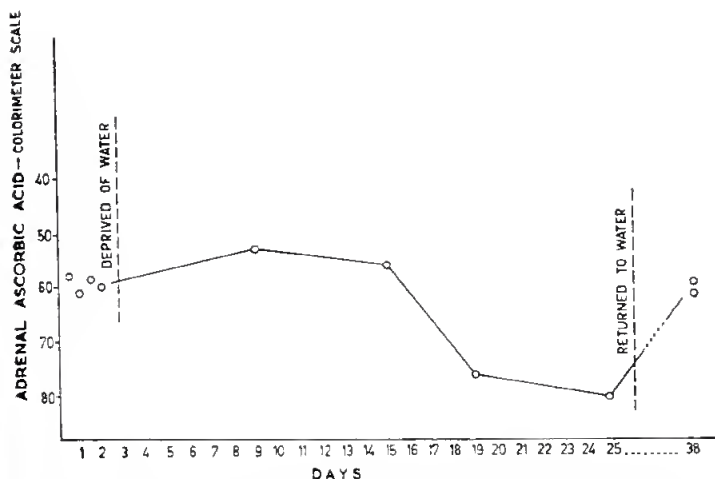


Fig. 4.—Levels of adrenal ascorbic acid in animals with conditions as in Fig. 3. Determinations were made on four animals before dehydration, four during dehydration and on two after being returned to water.

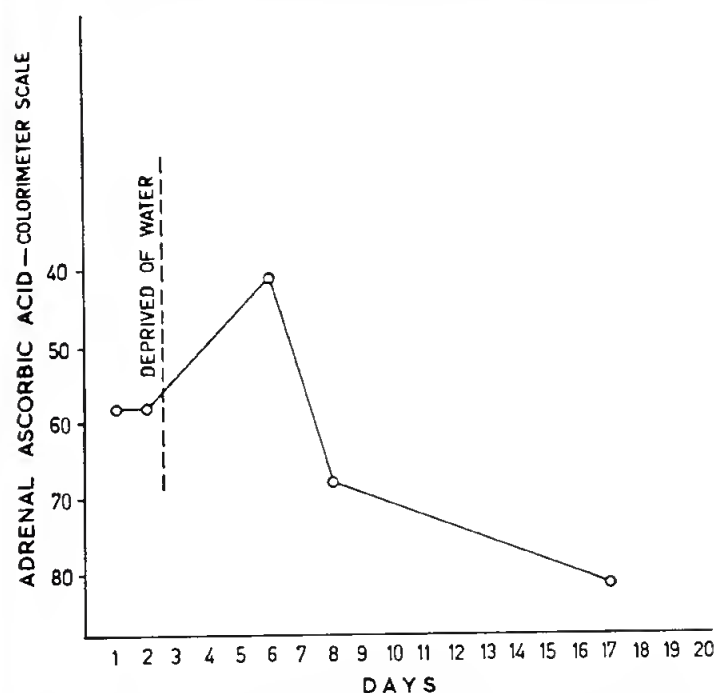


Fig. 5.—Levels of adrenal ascorbic acid in animals brought from a dry area of Rottnest Island and held without water.

A second group of seven animals was deprived of water and there was no green vegetation in the yard. These animals as in the first group had previously been held in pens with water and feed. Dry feed (sheep nuts) was available. As in the first group, there was a rise in adrenal ascorbic acid followed by a drop to low levels and finally a rise to normal after a return to water of approximately one week (Fig. 3).

The third group of ten animals subjected to experimental conditions as in group two, gave essentially the same pattern of adrenal ascorbic acid as in previous trials (Fig. 4).

Group number four consisted of animals brought from the "dry" area of Rottnest Island which were placed in a pen without water. These animals showed prompt changes in adrenal ascorbic acid levels and in a pattern similar to that of other groups but with the changes coming more quickly (Fig. 5). One animal died before examination.

It being established that (a) severe dehydration causes elevation, and then depletion, of adrenal ascorbic acid content (Figs. 2-4) and by (b) animals from "dry" areas on the island, although having approximately the same level

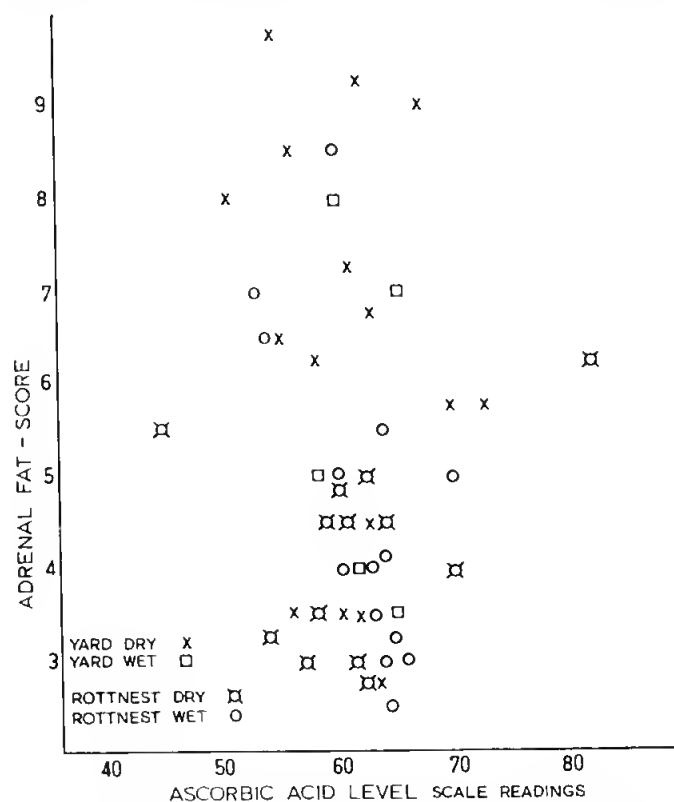


Fig. 6.—Adrenal ascorbic acid levels and adrenal fat scores showing no significant correlation between these factors. There was evidence, however, that Rottnest animals had less adrenal fat than animals kept in captivity.

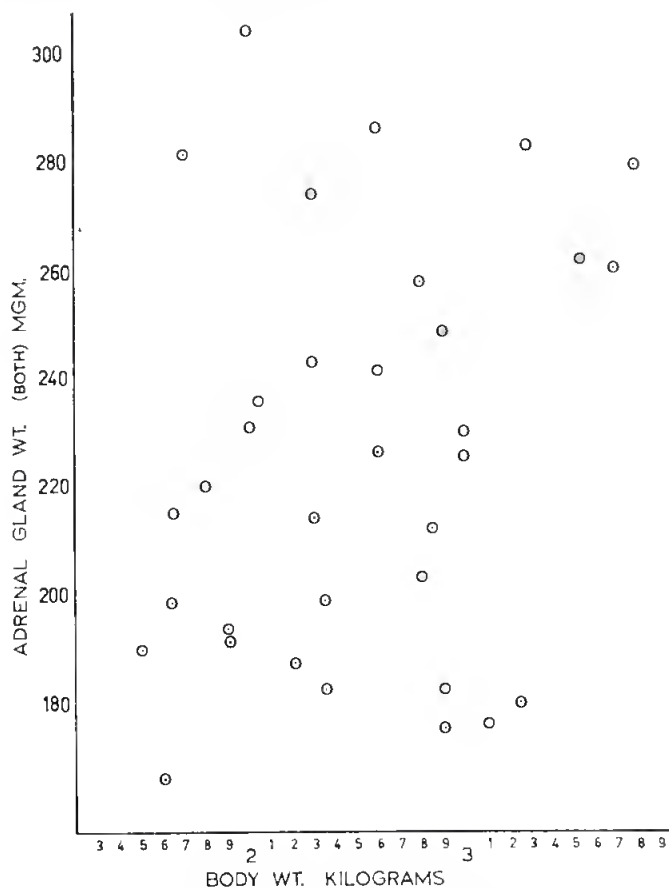


Fig. 7.—Body weight and adrenal gland weight gave only a low degree of correlation.

of ascorbic acid at the beginning of the experiment, showed a more dramatic ultimate depletion on complete dehydration (Fig. 5), an effort was made to get more animals from a "dry" area to see whether ascorbic depletion occurred in the wild during the low rainfall season. The animals captured had approximately the same adrenal ascorbic acid content as those captured previously. In all animals studied (yard and Rottnest) there was no significant correlation between adrenal fat and adrenal ascorbic acid levels. There was, however, a lower level of adrenal fat in animals from Rottnest Island than in most of the animals kept in captivity. There was no recognizable difference in adrenal fat in animals from the wet and dry areas of Rottnest Island. With all animals included, there was a low but significant correlation between body weight and adrenal gland weight. Body weight compared to adrenal fat likewise gave a low but significant correlation. Adrenal gland weight and adrenal ascorbic acid levels gave no significant correlation.

Discussion

Among animals kept in pens there was a consistent pattern of adrenal gland ascorbic acid level upon dehydration. In all cases there was an elevation of ascorbic acid in the earlier stages of dehydration. After a peak production, how-

ever, there was a drop in ascorbic acid that did not again rise during dehydration. Upon returning the animals to water in any stage of dehydration, adrenal ascorbic acid returned to usual levels in one to two weeks and this was accompanied by a rapid gain in body weight.

The adrenal glands of wild animals caught on Rottnest had ascorbic levels similar to those of animals held in pens and supplied with adequate feed and water. This was true even for animals taken from dry areas at the height of the summer. This may seem surprising but: (a) the summer of 1958 was not harsh and, (b) it is likely that the more vigorous animals were caught because on initial disturbance the weaker animals do not come out. Whatever the interpretation may be, it was demonstrated that severely dehydrated captive animals have a lowered adrenal ascorbic acid titre and that none of the wild ones taken had reached this level.

In view of the above it would plainly be valuable to test a larger number of animals, and particularly at the end of a harsh summer.

Summary

1. In the early stages of dehydration quokkas show a rise in adrenal ascorbic acid.
2. Continued dehydration results in a drop in adrenal ascorbic acid.
3. Upon returning dehydrating animals to water, adrenal ascorbic acid levels return to normal.
4. Wild animals from "dry" areas of Rottnest Island in 1958 did not show altered ascorbic acid levels.
5. Quantities of adrenal fat were not correlated with ascorbic acid levels.

Acknowledgments

Thanks are due to Mrs. Patricia Woolley (on salary paid by C.S.I.R.O.) for capturing animals and for generous technical help, to Mr. Jack Jeapes for care of animals, and to Mr. Bruce Rudeforth for technical help.

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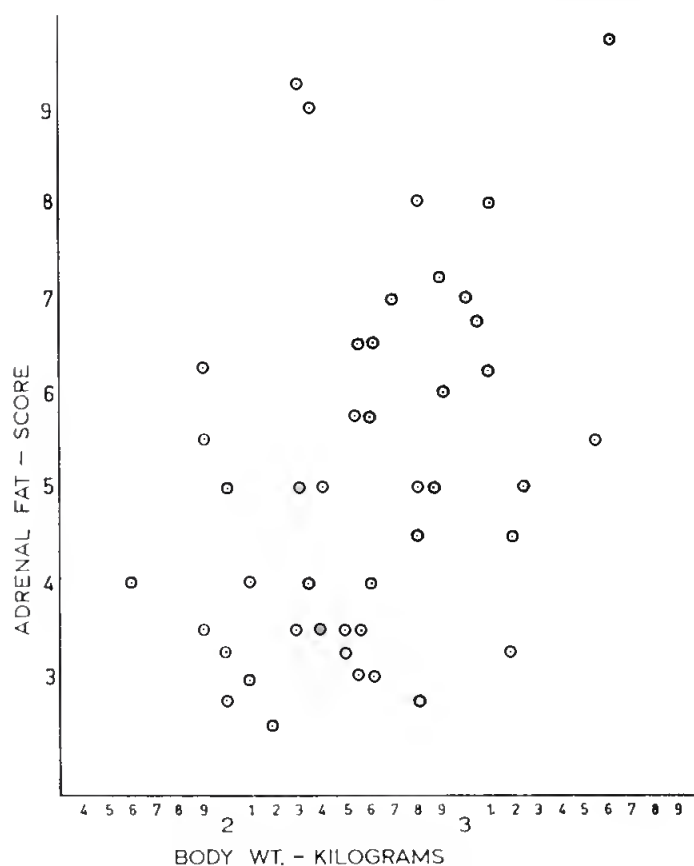


Fig. 8.—Body weight and adrenal fat score gave a low but significant correlation.

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Part 3

9.—A Naturally Etched Australite from Narembeen, Western Australia

By George Baker*

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A large boat-shaped australite weighing a little over 100 grams from Narembeen, Western Australia, has been naturally etched to produce abundant solution grooves on all surfaces. It is one of the very few, among some 40,000 known specimens of australites, that shows a sculpture pattern with prominent straight, circular and vermicular grooves resembling the U-shaped grooves on some specimens of billitonites and the "gouttières" on some indochinites. The grooves and pits on all surfaces of the specimen are essentially due to solution-etching that was primarily initiated along more readily etchable bundles of schlieren in the tektite glass. The longer grooves followed schlieren more or less parallel with the surface of the specimen; the pits and the circular grooves enclosing islands, thus producing structures resembling "höfchen" and "tischchen" on billitonites are an expression of differential solution along bundles of schlieren more or less normal to the surface of the specimen.

Introduction

A large boat-shaped australite showing pronounced grooves due to solution-etching was found on April 16th, 1960, by Mr. A. W. Henderson on a gravelled road 22½ miles due east of Narembeen, a township located at 32° 05' S. and 118° 25' E. in the South West Division of Western Australia and situated 155 miles east of Perth, Western Australia. The evidence points to the specimen having been carted in from a gravel pit four miles further east and situated five miles east of Mt. Walker at approximately 32° 05' S. and 118° 45' E.

The road was gravelled some six months prior to the discovery of the australite. The specimen is now lodged in the geological collection (Reg. No. 8950) of the School of Mines of Western Australia, Kalgoorlie.

Size and Weight

The australite measures 64 mm in length, 37 mm in width and 30.5 mm in depth (= thickness). Its weight after thorough cleaning to remove all adventitious particles of terrestrial matter is 107.457 grams, but this is not the total weight of the solution-etched specimen as found, since a small, highly vitreous fractured face occurs at one end of the anterior surface (see dark area at top left-hand end

of Fig. B, Plate I). This fracture is of very recent origin as it shows no signs of having been etched; there is no evidence to show that fracturing was due to skilled aboriginal flaking and occasional "bruise-marks" on the anterior surface near the fracture suggest that the specimen was struck with a hammer.

The specific gravity as determined on a Mettler K-type balance in distilled water ($T_{H_2O} = 12.8^\circ \text{C.}$) is 2.431. This is above the average for australites generally (cf. Baker and Forster 1943, p. 403), but lower than the average for seven boat-shaped australites from the Coolgardie district of Western Australia (Baker and Forster 1943, p. 385), and higher than most specific gravity values for australites from eastern Australia (Baker and Forster 1943, Table 3).

Only twelve other australites are known to science that weigh over 100 grams, and one-third of these are boat-shaped forms.

Curvature of Surfaces

Approximate values for the radii of curvature of the posterior and anterior surfaces as measured along the long axis of the specimen are:

$R_B = 57.9 \text{ mm.}$

$R_F = 46.2 \text{ mm.}$

where R_B = radius of curvature of the posterior (back) surface and R_F = radius of curvature of the anterior (front) surface, nomenclature of the surfaces being according to the flight orientation through the atmosphere. The anterior surface thus shows a rather steeper arc of curvature compared with the posterior surface. The surface curvatures along this direction are not quite coincident with the arcs of curvature of constructed circles having the above radii, being a little flatter in the polar regions and somewhat steeper near the equatorial edge.

Across the width or shorter diameter of the specimen, the arcs of curvature of both the posterior and the anterior surfaces more closely fit those of constructed circles with the same radius of curvature, and both R_B and $R_F = 21.0 \text{ mm.}$ A cross section of the specimen, however, is not circular (cf. end-on view, Fig. D, Plate I) because the centres of the two arcs of curvature

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are not coincidental, being 11.1 mm apart on the same axis (the polar axis as projected in the line of flight). The constructed circles are coaxial and the centres collinear. Reconstruction of the form to its complete state prior to modification by aerodynamic frictional heating during high speed flight through the earth's atmosphere, reveals that a depth of 11.1 mm was removed by ablation of tektite glass from the front polar regions (i.e. at the stagnation point —cf. Baker 1961b) on the anterior surface.

Refractive Index and Silica Content

The refractive index of the tektite glass constituting this australite from Narembeen, as determined by the Immersion Method utilising monochromatic (Na) light is:—

n_{Na} 1.508 to 1.510 for schlieren of slightly different chemical composition. From the relationship $k = n - 1/d$, the specific refractivity (k) of the glass is 0.2094. (n = refractive index; d = specific gravity).

Tektite glass with a specific gravity of 2.431 and a refractive index of 1.509 (average of measurements), contains approximately 71 per cent. SiO_2 according to the Silica-Refractive Index and Silica-Specific Gravity graphs for tektites generally (cf. Barnes 1940; Baker 1959).

Nature of Sculpture

The australite from near Narembeen shows marked evidence of having been subjected to relatively strong solution-etching (Plate I) while buried in thin superficial terrestrial materials (sandy to gravelly soils). This has produced etch pits and both straight (linear and forked) and meandrine shallow grooves, the deeper of which sometimes cut across the trends of shorter, shallower grooves. The greatest width of the grooves is 1 mm; they are 0.5 mm to 1 mm deep and open U-shaped in cross section (cf. top right, Fig. C, Plate I).

The specimen is one of the very few australites on which the corrosion sculpture constituted largely of vermiform grooves and etch pits is so marked as to strongly resemble similarly solution-etched specimens of certain billitonites and indochinites. The sculptural detail is shown in Plate I, figures A to E, and this compares with the sculpture of billitonites (cf. Baker 1959, Plate I, Figs. A to D), although many grooves on the billitonites are often somewhat deeper than those on this australite.

The aerodynamically stable orientation of australites during unidirectional, non-rotational transit at high speeds through the earth's atmosphere is such that the anterior surface remains projected forward in the line of flight throughout the ablative phase. On this basis, the fact that the grooves are as equally well-developed on both anterior and posterior surfaces is adequate confirmation of the postulate

that such grooves are not elements (i.e. piézo-glyphs) of a sculpture pattern produced by aerodynamic friction and ablation during earthward flight, for the posterior surface was never exposed to the action of aerodynamic friction in the sense in which the anterior surface was exposed.

Furthermore, the results of etching experiments on worn australites (Baker 1961) substantiate the theory that such grooves or channels are a result of solution-etching by sub-aerial terrestrial agents that came into operation after the australite had landed upon the earth's surface.

Many of the solution grooves follow the trends of certain flow-line directions that consist fundamentally of rather more etchable schlieren, hence the surface pattern of the chemically corroded form is essentially an external expression of a relatively complex streaky internal structure. The long and short grooves, whether straight or meandrine, occupy the sites of bundles of schlieren trending parallel with the surface of the tektite. Circular grooves enclosing small islands of tektite glass and forming structures resembling the better developed "höfchen" and "tischchen" structures on billitonites are formed in regions where the bundles of schlieren trend more or less normal to the tektite surface; the more readily etchable groups are dissolved to leave roughly circular grooves enveloping less readily attacked "small tables" (cf. Plate I, Fig. B, left-hand end). Finer flow-lines ("fiederung") trending across some of the vermiform and circular grooves in places result in a segmented appearance detectable under higher magnifications (e.g. with a 10× hand-lens). The smaller, round, more regular pits on the surface of the tektite are evidently "outcrops" of internal small bubbles exposed by removal of the outer zones of the glass by chemical corrosion.

With more pronounced solution-etching along certain directions than along others, some of the deeper grooves so truncate shallower channels that they end abruptly at the walls of the deeper grooves and remain as small U-shaped "hanging valleys". Differential solution of this nature is probably a reflection of more constant supplies of etchant (soil solutions) that became directionalised along certain trends determined initially by compositional differences from schliere to schliere. Once the process was initiated, there would be a tendency for etchants to lodge for somewhat longer periods in small depressions on the specimen. The sub-arid nature of the area where the specimen was discovered suggests that etchants would only be periodically available throughout the year, but supplies could have been rather variable during the past 5,000 years that the specimen has lain in soils on the earth's surface (cf. Baker 1961a).

PLATE I.

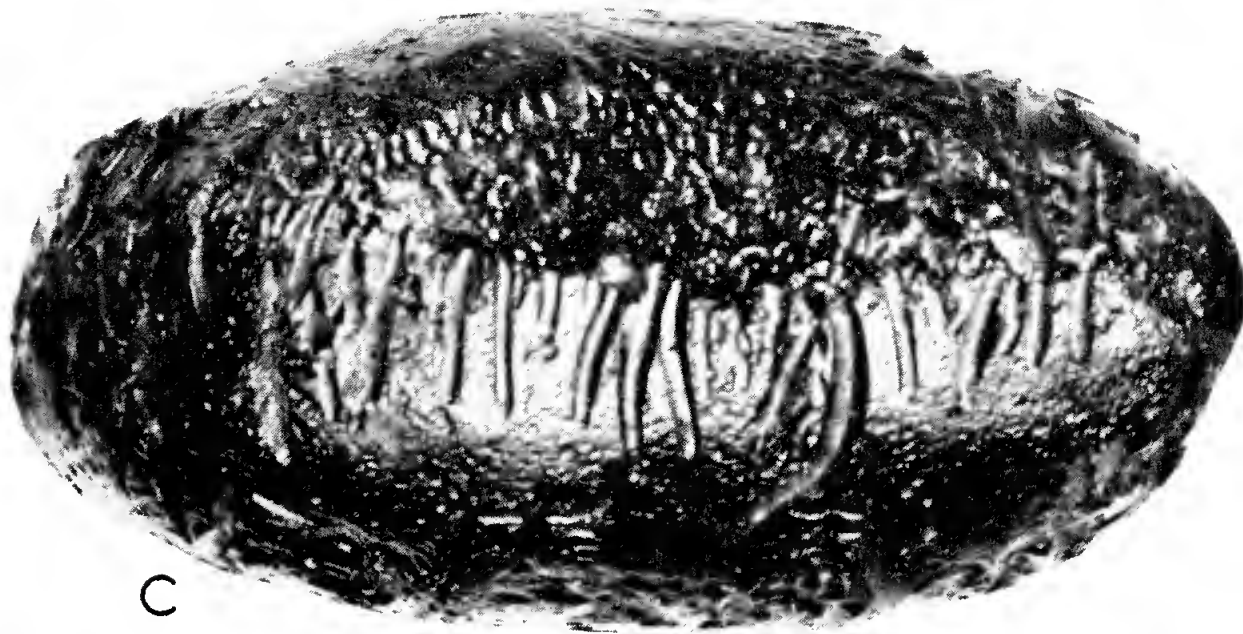
Boat-shaped australite from gravelled road 22½ miles due east of Narembeen, Western Australia. (Reg. no. 8950. Geological Collection, School of Mines of Western Australia, Kalgoorlie). Figures A to E show solution etch grooves on all surfaces, some extending from the posterior to the anterior surfaces and cutting across the rim (Figs. D and E), others terminating at the rim (Fig. C). A = anterior surface ($\times 1.16$); B = posterior surface, slightly chipped at left-hand end ($\times 1.20$); C = side view (reverse side to Fig. E), with posterior surface at top ($\times 1.92$); D = end-on view, with posterior surface at top ($\times 1.05$); E = side view (reverse to Fig. C), with posterior surface at top ($\times 1.20$). (Photographs by K. L. Williams.)



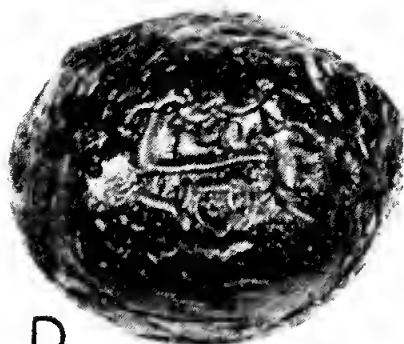
A



B



C



D



E

Comparison with Other Large, Boat-shaped Australites

Compared with other large, but not as heavy boat-shaped australites such as from Kaniva (95.85 grams), Ellerslie (47.75 grams) and Port Campbell (29.48 grams) in western Victoria (Baker 1940, Plate XII, Figs. 1, 5 and 9), the specimen from Narembeen reveals much more prominent and more abundant, deeper solution grooves. Furthermore, it does not possess a naturally flaked equatorial zone like these specimens, and thus resembles a boat-shaped specimen (88.45 grams) from Corop, Victoria (Baker 1940, Plate XXII, Fig. 2) and another (141.63 grams) from Port Campbell, Victoria (National Museum of Victoria, Reg. No. 11402), except that the rim separating the anterior and posterior surfaces is not nearly as well-preserved on the Narembeen specimen.

The absence of a flaked equatorial zone (cf. Baker 1940, p. 488) which is normally a common feature of the larger australites such as round cores, oval cores and boat-shaped cores, raises the question (a) whether a flaked equatorial zone was present when the Narembeen boat-shaped australite landed, and whether this flaked zone was subsequently destroyed by advanced degrees of solution-etching especially in the equatorial regions, or (b) whether a flaked equatorial zone did not develop during atmospheric flight for the reason that the initial angle of entry might have been too high for aerodynamic friction and heating to cause fusion stripping in equatorial regions. The appearance of the form in side and end-on aspects is such as to lend some support to (b). Furthermore, Fenner (1935, p. 130) has figured a few specimens of australites under the term "indicators" which show flaked equatorial zones developing largely as a consequence of subaerial erosion, but these

are usually much smaller specimens than the example studied herein.

Whether or not some flaked equatorial zones are due to fusion stripping during atmospheric flight and others to subsequent corrosion and flaking from the action of subaerial agencies operating after the australites landed upon the earth's surface, it is apparent that both processes can have been responsible in reducing, or in combining to reduce, the bulk of the primary form of the boat-shaped australite from Narembeen by at least one-third, and probably more.

Acknowledgments

The specimen was kindly submitted by W. H. Cleverly, B.A., B.Sc., head of the Geology Department, School of Mines of Western Australia, Kalgoorlie for examination. Mr. Cleverly also provided details of the discovery and mode of occurrence of the australite.

The author is indebted to Professor Rex T. Prider for communicating the paper through his membership of the Royal Society of Western Australia.

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10.—Vertebrate Localities in the Triassic Blina Shale of the Canning Basin, Western Australia

By K. G. McKenzie*

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The Blina Shale is recorded from the Fitzroy Trough which occupies the northern sector of the Canning Basin.

The author, as a member of a joint expedition to the Fitzroy Trough from the Western Australian Museum and the Museum of Palaeontology, Berkeley, California, stratigraphically mapped the Blina Shale at Erskine Range. An important fossil vertebrate collection was made here.

Other localities mapped as Blina Shale were prospected and two new localities were discovered. At one of these (1½ miles ENE. of Bore 20, Noonkanbah Station) a certain amount of useful vertebrate material was found.

Detailed descriptions of the 104' of Blina Shale and 58½' of Erskine Sandstone exposed at Erskine Range are given below.

The sedimentary characters and the palaeo-ecological implications of the fauna and flora indicate that deposition took place on the sub-aqueous topset plain of a marine delta.

Introduction and Previous Work

The Blina Shale is recorded from the central portion of the Fitzroy Trough which occupies the northern sector of the vast Canning Basin in the north west of Western Australia. The formation, however, is poorly exposed in the Trough and no type section has been described.

Geologists of the Bureau of Mineral Resources spent several field seasons in the Fitzroy Trough from 1948 through to 1952 (Guppy, Lindner, Rattigan and Casey 1958). They mapped the Blina Shale at Erskine Range and also identified several outliers of this formation in marginal synclines. Brunnschweiler spent some time in the field with the Bureau parties, and later, working with Bureau collections, recognised Triassic affinities in the fauna of the Blina Shale. He described a vertebrate and invertebrate fauna from the formation, noting the presence of a basal "bone bed" (in the Dry Corner area, approx. 124° 07' E., 18° 21' S.) and ascribed the Blina Shale and the overlying Erskine Sandstone to the Upper Triassic, suggesting that the two units be included in the Derby Group (Brunnschweiler 1954). This was the first record of marine Triassic in the Fitzroy Trough. Brunnschweiler argued that a slight angular unconformity separated the Blina Shale and the underlying Permian Liveringa Formation but more recent work indicates that these formations are disconformable. The micro-plankton suite of the Derby Town Bore (McWhae, Playford, Lindner, Glenister, and Balme 1958 p. 83) shows no considerable break be-

tween the Blina Shale and the Liveringa Formation, and Balme has suggested a Lower Triassic age for the Blina Shale, with affinities to the Kockatea Shale in the Perth Basin.

The Kockatea Shale is Lower Triassic in age (Dickins, McTavish, and Balme 1961).

Hitherto there has been no record of fossil vertebrates from the upper part of the Blina Shale.

Method

General

On the initiative of Professor R. A. Stirton, Director, Museum of Palaeontology, Berkeley, California, it was decided to equip a joint expedition to the Fitzroy Trough from the Museum of Palaeontology, Berkeley, California, and the Western Australian Museum.

The expedition consisted of Professor C. L. Camp, party leader, and Mr. J. Cosgriff, both of the Museum of Palaeontology, and Mr. D. Merri- lees and the author, both from the Western Australian Museum and the University of Western Australia. Dr. W. D. L. Ride, Director, Western Australian Museum, was with the party in the initial stages until the arrival of Merri- lees.

In the field the plan was to visit and prospect every outcrop of the Blina Shale for fossil vertebrates. The best areas would then be selected for further detailed work, with the Americans specialising in the palaeontology and the Australians doing the mapping. The success of the mapping project owes much to the ready assistance of Merri- lees.

Consequently, when it was decided to concentrate on the Erskine Range locality, Camp and Cosgriff prospected and quarried proven beds in the area while McKenzie and Merri- lees mapped the thickest exposed section.

Lithological samples are deposited in the collection of the Western Australian Museum, and the vertebrate collections have been divided by agreement between the Museum of Palaeontology, Berkeley, California, and the Western Australian Museum.

Mapping

A West Australian Petroleum Pty. Ltd. gravity station GM 75 11277 in the Erskine Range was used as a height datum and closed traverses were run to all quarry localities in the Range. This part of the mapping was carried out at a scale of 1" = 200'. The detailed mapping of the section at Locality 4 was carried out at 1" = 100' (see Fig. 1).

Plane table and telescopic alidade were used to map the exposures. Where exposures were

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THE BLINA SHALE AT ERSKINE RANGE

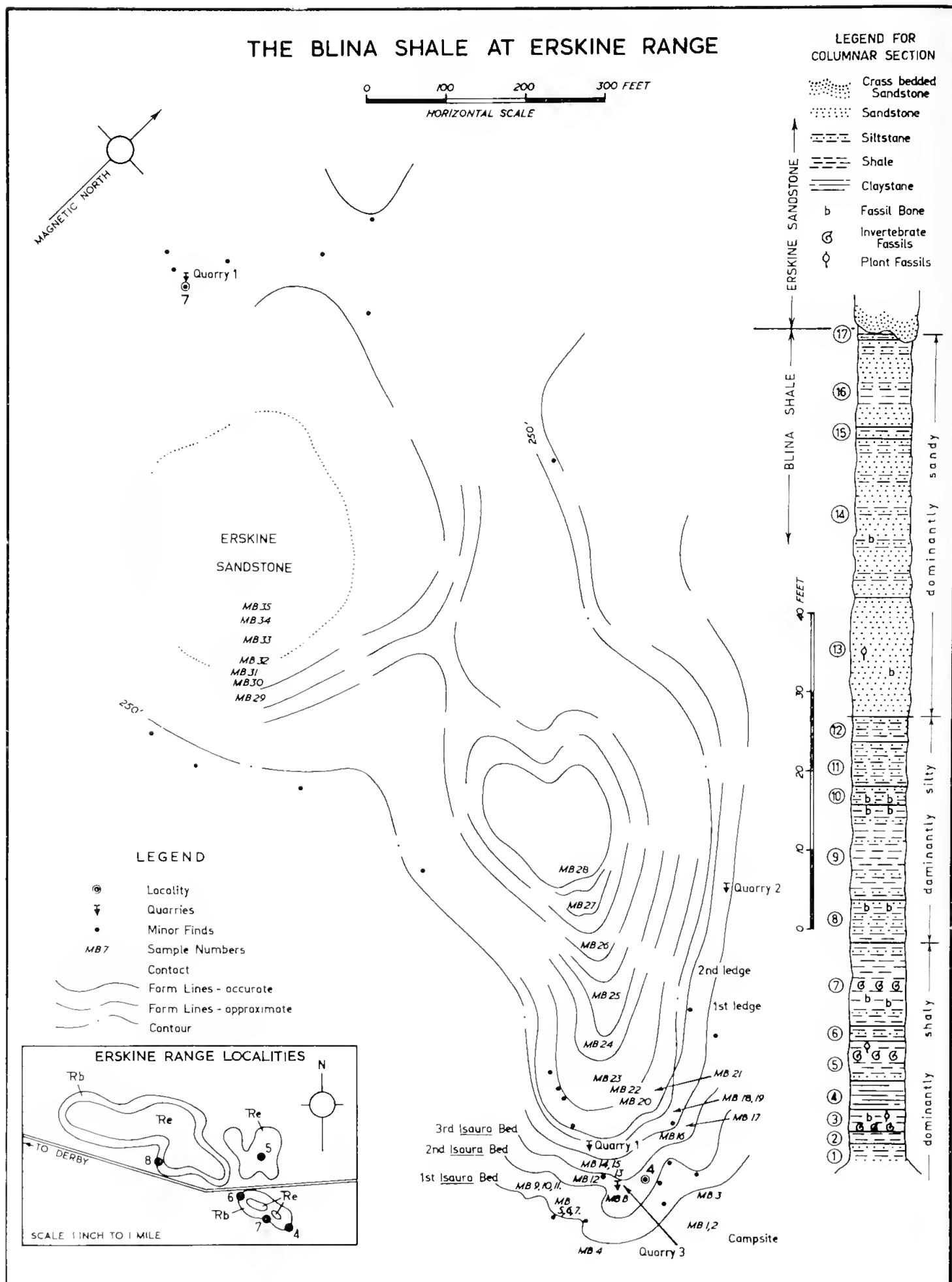


Fig. 1

covered by scree, as commonly happened, the hillside was dug into until fresh rock was exposed. Where exposures were poor in the vertical plane, but better to left or right, beds were traced to these better exposures and the sectioning continued. In this way the whole Blina Shale section exposed at Locality 4 was mapped with only one break. This break occurred at the top of the most southerly hill in the Range (Locality 4). From this point the mapping was transferred to the next hill to the north. As the Blina Shale dips uniformly, it was possible to compute the stratigraphic position of the break so that the section could be compiled without loss or overlap.

The lithology was recorded in detail throughout the section and samples were taken at frequent intervals.

Following completion of this part of the programme, the Blina Shale/Erskine Sandstone contact was mapped at Localities 4, 6, 7 and 8 to test whether it was a disconformity (see Fig. 1).

Mapping at Erskine Range was completed in eleven days. No mapping was done elsewhere.

Stratigraphy of the Blina Shale

The outcrop at Erskine Range is the major exposure of Blina Shale in the Fitzroy Trough. Only one other outcrop can be located stratigraphically with any precision; at Dry Corner the basal beds are exposed but the contact with the nearby underlying Liveringa Formation is not.

The only area visited which afforded any scope for further palaeontological work or for stratigraphic correlation, was Erskine Range where the Erskine Sandstone/Blina Shale contact is more or less well exposed throughout the whole range. Detailed stratigraphic mapping, therefore, was commenced at Locality 4 (124° 21' 40" E., 17° 51' 25" S.), Erskine Range, in conjunction with a more intensive search for vertebrate material. Since the top of the sequence is missing at Locality 4, the upper 11½' of section was mapped in the next hill to the north.

In this area the Blina Shale strikes N70 W and dips uniformly 01° NE.

The section measured is shown below:

Erskine Sandstone overlying:

(Contact zone) *sandy siltstone*, quartzose, slightly micaceous, ferruginised, purplish, hard, thickness varying up to 1 in., in places includes horizons containing light coloured, flat silt pellets. Feet

- (17) *sandy siltstone*, quartzose, micaceous, light coloured to purplish to yellow-brown, thin-bedded, laminated with colour-variegation between laminae 0-½
- (16) *sandy siltstone to sandstone*, quartzose, micaceous, light brown to whitish, some iron-staining, weathers friable, thin-bedded, in part laminated with slight colour-variegation, sandier beds are thicker, very fine-grained, sub-angular, medium-sorted with a silty cement ½-11½
- (15) *sandy siltstone to silty sandstone*, quartzose, micaceous, dark brown to pinkish brown, iron-enriched and hardened with some development of iron-rich leaching structures, friable where not hardened as a result of

iron-enrichment, thin-bedded, laminated with some colour-variegation, very fine-grained, sub-angular, medium-sorted, prominent brown silty cement, broad ripple marks poorly developed 11½-13

- (14) *silty sandstone to sandstone*, quartzose, micaceous, pale buff to whitish, in many places strongly ferruginised with remarkable development of iron-rich leaching structures in resistant ledges (these are secondary features, cylindrical, vertical, concretionary, often developing blisters on the under surfaces of beds), friable where fresh, probable broad ripple marks developed, bedding poorly expressed possibly thin-bedded, occasionally laminated, exhibiting gentle cross-lamination but little colour-variegation, very fine-grained, sub-angular, medium sorted, with abundant to minor silty cement. Rarely fossiliferous carrying vertebrate material 13-33
- (13) *sandstone*, quartzose, micaceous, pinkish brown to buff, some horizons are iron-enriched and hardened forming resistant ledges with prominent iron-rich leaching structures, incipient similar structures in other beds, friable where fresh, bedding obscure probably thin-bedded, indistinct laminations rare, very fine-grained, sub-angular, medium-sorted, minor silty cement. Rare plant material found in scree at this level also one piece of bone 33-48
- (12) *siltstone to silty sandstone*, quartzose, very slightly micaceous, brown to purplish brown, iron-enriched and hardened resistant ledges present with prominent iron-rich leaching structures, thin-bedded, occasionally laminated, with slight colour-variegation and gentle cross-lamination, very fine-grained, sub-angular with a brown silty cement 48-51½
- (11) *silty shale to siltstone*, quartzose, micaceous, pale buff, mauve-tinted at base, grading to whitish grey with yellow-brown iron-mottling at top, friable, massive with one thin well-laminated band at 54½ ft., iron-rich leaching structures developing at top 51½-56½
- (10) *siltstone to sandy siltstone*, quartzose, micaceous, mauve colour with a dark yellow-brown iron-rich concretionary band 1 in. thick at 57½ ft., friable, massive, sandier horizons are quartzose, sub-angular, with a dominant silty cement. Fossil vertebrate material found in situ 56½-59½
- (9) *silty shale*, quartzose, blue-grey when fresh, alters to purplish to dark brown due to iron-enrichment which has developed a resistant ledge in the upper 2 ft. and minor resistant bands below this including a thin, hard, purplish-red iron-rich concretionary band at 67½ ft., friable where weathered, where fresh has a conchoidal fracture, no bedding discernible in the fresh rock but thin-bedding and laminations, some displaying gentle cross-laminations, noted as it weathers. The ledge contains vertebrate material in place (second ledge) 59½-71½
- (8) *siltstone to silty sandstone*, quartzose, micaceous along bedding planes, fresh rock is pale buff to yellowish with yellowish streak, conchoidal fracture, but purplish to dark brown where iron-enriched, friable where weathered, thin-bedded and indistinctly laminated in part, very fine-grained, sub-angular, well-sorted with a buff coloured silty cement. A prominent resistant ledge (first

- ledge) hardened by iron-enrichment is developed between 71½ ft. and 73½ ft. the upper few inches of which contain abundant vertebrate material. This ledge has been prospected with success along much of its outcrop and quarried in the more promising localities (Quarry 1 and Quarry 2) 71½-76½
- (7) *shale to silty shale*, quartzose, slightly micaceous towards base, pale blue-green where fresh, but often strongly iron-stained yellow to yellow-brown, incipient iron-rich nodular and leaching structure zones common, friable where weathered, bedding indistinct, probably thin-bedded. Vertebrate material located in situ at 84½ ft. associated with small yellowish acicular gypsum crystals. The locality has been quarried (Quarry 3). The first skull found was picked up on the talus slope just below this level. The third *Isaura* marker bed occurs at 81½ ft. This bed is variable in thickness up to 3 in. These *Isaura* beds have a pitted weathered surface (due to removal of calcareous shell material) that enables them to be readily identified among the talus 76½-87
- (6) *silty shale*, quartzose, purplish-brown, with a reddish streak, thin-bedded, in part distinctly laminated with alternating light and dark laminae 87-89
- (5) *shale to shaley siltstone*, quartzose, micaceous along bedding planes, buff colour, reddish streak, friable where weathered, thin-bedded (average thickness of beds at base ½ in. thickening to 2 in. at top), in part laminated with slight colour-variegation. Thin iron-rich, purplish-red siltstone bands occur at 91½ ft., 92½ ft., and 93½ ft. An *Isaura* bed occurs at 90½ ft. below a 2 in. thick dark buff-coloured bed. At the top of the sequence a well-preserved plant specimen was found in situ 89-94
- (4) *claystone to shale*, greenish-grey, conchoidal fracture with shiny fracture surfaces, greasy feel, slight earthy odour, massive generally but in part thin-bedded indistinctly. Band of hard dark brown iron-rich nodules, averaging 3 in. long and 1 in. thick at 97 ft. 94-97½
- (3) *shaley siltstone to shale*, blue-grey to buff, friable where weathered, thin-bedded, fossiliferous. The first *Isaura* bed occurs at 99½ ft., thickness varying up to ½ in. Immediately above this, vertebrate material is found in situ associated with occasional *Isaura*-like fossils and lingulid brachiopods, and with small yellowish acicular gypsum crystals. Towards the top of the sequence a buff coloured harder band about 2 in. thick contains similar estheriids and brachiopods 97½-100
- (2) *silty shale to siltstone*, quartzose, micaceous, grey to buff, in part iron-stained, friable where weathered, thin-bedded, laminated exhibiting cross-laminations and colour-variegation, earthy odour at base. A thin discontinuous band of purplish iron-enriched siltstone occurs at the top of the sequence 100-101½
- (1) *shale to silty shale*, pale greenish-grey, containing incipient iron-rich leaching structures, purplish-brown ferruginised zone at 102½ ft., friable where weathered, thin-bedded in part laminated, becoming micaceous at top. Rare, clean, ½ in. long quartz pods present, poorly cemented, very fine-grained, sub-angular, medium-sorted with dominantly frosted surface textures 101½-104

It was noted throughout the section that weathering has accentuated features such as bedding, lamination, cross-lamination and colour-variegation which tend to disappear as the formation is quarried into. Features such as ripple marks are usually poorly defined, but one definite ripple-marked surface was disclosed at Locality 8 by careful quarrying.

In addition to the fossiliferous beds listed above at Locality 4, vertebrate material was found loose above Locality 7 on a saddle about 25 ft. below the Erskine Sandstone/Blina Shale contact, and in place at Locality 7 about 45 ft. below this contact (see Fig. 1). At Locality 6 an amphibian skull was found in the talus. The matrix of this skull was tentatively matched with rock in a ledge a few feet above the spot where the skull was found and about 60 ft. below the contact. And at Locality 8 where vertebrate material was quarried from a ledge about 60 ft. below the contact, rocks immediately below the contact itself contained bone in place. Other finds are marked on Fig. 1.

The other mapped areas of Blina Shale fall into three categories: those represented by bedded exposures, those represented by residual rubbles, and the breccia rims associated with the Fitzroy Volcanics at White Rocks and Wolgidee Hills. Brief descriptions of these areas are given in Tables I, II and III.

TABLE I.
Bedded Exposures.

| Locality | Morphology | Lithology, Structure, Thickness | Fossils |
|--|-----------------------------------|---|--|
| Wongil Ridge Yeeda Station. 123° 45' E., 17° 38' 30" S. | Low rise capped by laterite | Horizontal, micaceous, quartzose siltstones and very fine-grained sandstones, thin-bedded, laminated, variegated pale pink and yellowish uniform, blue-green, puggy fractured clay, 25' thick | Plants, trails |
| Brennan's Bore Noonkanbah Station. 125° 12' E., 18° 16' 30" S. | Two low mounds and dry well shaft | | None found |
| North of Wolgidee Hills Noonkanbah Station. 125° 50' 30" E., 18° 16' 30" S. | Low mesa capped by laterite | Horizontal, micaceous, quartzose very fine-grained sandstone with abundant silty cement, thin-bedded, blue-grey to whitish grey. About 30' thickness exposed | None found |
| 1½ miles ENE Bore 20 Noonkanbah Station. 124° 47' 30" E., 18° 10' 30" S. | Low rounded hill | Rubbly outcrop. Quarrying should disclose fossiliferous strata. New locality for Blina Shale | Amphibian remains, fish scales. |
| Bore 20 Noonkanbah Station. 126° 46' E., 18° 11' S. | Bore section | Puggy, blue-grey clay | Fossil plants and "insects" (Wade 1936 via Guppy 1958) |

TABLE II.
Residual Rubbles.

| Locality | Morphology | Lithology, Structure, Thickness | Fossils |
|---|-------------------------------|--|--|
| Between Bauman's and Minosa Bores, Blina Station, 124° 32' E., 17° 40' S. | Slight topographic rise ... | Ferruginised rubble of yellow-brown to brown, micaceous, quartzose, very fine-grained, sub-angular, medium-sorted sandstone with a silty cement | One fragment of amphibian bone found |
| Ryan's Bore, Blina Station, 124° 28' 30" E., 17° 41' 30" S. | Level plain ... | Dark greenish-yellow soil containing pale brown gypsum crystals, occasional ferruginised siltstone rubble | None found |
| SE of Telephone Dam, Kimberley Downs Station, 124° 20' E., 17° 28' S. | Level plain | Three small patches of ferruginised rubble | None found |
| SW of Willumbah, Liveringa Station, 124° 15' E., 17° 56' S. and 124° 15' E., 17° 57' S. | Low rise ... | Ferruginised conglomerate overlying the Permian Liveringa Formation | None found |
| Across track between Erskine's Well and Boab Tank, Liveringa Station, 124° 20' E., 17° 54' S. | Level plain | Dark greenish-yellow soil, occasional ferruginised rubble | None found |
| Boab Tank, Liveringa Station, 124° 17' E., 17° 53' S. | Level plain, excavated tank | Yellow-brown, vaguely bedded, slightly cross-bedded and laminated, fine-grained, sub-angular, well-sorted, micaceous quartz sandstone with minor cement. Probably belongs to Erskine Sandstone | Trails (?) |
| One mile S. of Egan's Bore, Paradise Station, 124° 33' E., 17° 57' 30" S. | Level plain ... | Rubble of flattish boulders consisting of dark brown cobble conglomerate with a matrix of fine-grained calcarenite having a silty cement | <i>Isaura</i> , amphibian bone fragments including clavicle |
| Dry Corner area, Nerrima Station, 124° 05' 30" E., 18° 21' S. | Generally flat with low rises | Synclinal area. Ferruginised conglomerate and rubble. But note that Bureau of Mineral Resources geologists collected amphibian material from here described by Brumschweiler (1954). The joint Museum expedition unfortunately could not re-establish the locality although some days were spent in the area | <i>Lingula</i> , <i>Isaura</i> , amphibian remains, fish scales (Brumschweiler 1954) |
| Bore 6, Noonkanbah Station, 124° 45' E., 18° 20' S. | Level plain ... | Dark greenish-yellow soil containing gypsum crystals, occasional rubble | One fragment of amphibian bone |
| Jubilee Dam, Quambun Station (= Alligator Dam, Guppy <i>et al</i> 1958, = a tank on Quambun Station, Glauret 1921). 124° 14' E., 18° 18' 30" S. | Excavated dam | Soil contains gypsum crystals | Pleistocene crocodilian remains (Glauret 1921, 1926) |

TABLE III.
Breccia Rims.

| Locality | Morphology | Lithology, Structure, Thickness | Fossils |
|---|--------------------------------------|---|--|
| White Rocks, Noonkanbah Station, 124° 46' E., 18° 12' S. | Breccia rim of the Fitzroy Volcanics | Country rocks have been brecciated, metamorphosed, stained green, re-cemented and hardened as a result of intrusion by lamproite bodies | None found |
| Wolgidee Hills, Noonkanbah Station, 124° 51' 30" E., 18° 19' S. | As above ... | Lithology as above. New locality. Note that in August 1955, Prider noted the presence of a dark green hornfelsed shale in this area (Professor R. T. Prider, personal communication) and sampled this shale (Geology Department, University of Western Australia, Sample No. 42615) | <i>Isaura</i> , a bone fragment, a few large pieces of fossilised wood and several small ones collected. Sample No. 42615 is <i>Isaura</i> -rich |

The only area not visited by the party was the large area, tentatively mapped as Blina Shale, south-west of Halls Creek. As the region is not easily accessible and the correlation was known to be tentative (R. M. L. Elliott, personal communication) it was felt that a trip there was not justified in view of the heavy demands it would make on the party and the probable lack of success that would result.

The Erskine Sandstone

The Erskine Sandstone at Erskine Range was examined in less detail than the Blina Shale.

Plant collections were made from the Erskine Sandstone at Locality 5, Erskine Range, from

The Sisters Plateau and from Yarrada Hill, but no attempt was made to locate these collections stratigraphically in the sequence described below.

Boulders of Meda Formation

- | | |
|---|-------------------|
| (3) sandstone, quartzose, whitish, iron-stained yellow-brown to purplish-pink, friable to crumbly, thick-bedded becoming thin-bedded at the top, strongly cross-bedded, laminated with marked colour-variegation and cross-lamination, extensively ripple-marked even on cross-bedded surfaces, mud-cracked, fine-grained, sub-angular, medium-sorted, with dominantly frosted surface textures and minor cement. Locally micaceous | Thickness Feet |
| ..... | About 30 |

- (2) *sandy siltstone*, quartzose, slightly micaceous, whitish, thick-bedded, cross-bedded, laminated with colour-variegation, whitish silty cement. The basal bed is ripple-marked, while the uppermost bed is mud-cracked. The unit includes a lens of medium-grained quartzose sandstone, cross-bedded, with prominent silt pellet horizons. The enclosing surfaces of this lens are thin purplish ferruginous siltstone bands which are ripple-marked 30-36½
- (1) *sandstone*, quartzose, micaceous, friable to crumbly, whitish to creamy, medium to thick-bedded, strongly cross-bedded, laminated and gently cross-laminated with some colour-variegation, carrying rare silt pellets, fine-grained to very fine-grained, sub-angular, medium-sorted, with dominantly frosted surface textures. Two feet below the top is a 1 in. thick purplish ferruginised siltstone band associated with rich silt pellet horizons. At the top of the sequence is a similar siltstone band 36½-58½
Contact with the Blina Shale.

Mapping at Localities 4, 6, 7 and 8, disclosed that the contact between the Erskine Sandstone and the Blina Shale is a disconformity (see Table IV). The time break is probably a small one, being represented by the thin ferruginised siltstone described.

TABLE IV

Heights of the Erskine Sandstone/Blina Shale contact, with respect to Locality 4, corrected for dip of the Blina Shale, to show that the contact is a disconformity.

| Locality | Height a.s.l. ft. | Height w.r.t. Locality 4 |
|-----------------------|----------------------|-----------------------------|
| | | corrected for dip ft. |
| At Locality 4 | 317.22 | 0.00 |
| At Locality 7 | 322.20 | 4.98 |
| At Locality 6 | 326.40 | 17.03 |
| At Locality 8 | 307.65 | 4.18 |
| NE of Locality 8 | 295.65 | 2.13 |
| NE of Locality 8 | 304.50 | 16.21 |

Brunnschweiler (1954) has assigned the Erskine Sandstone to the Upper Triassic. On the basis of the microflora, however, Balme considers that the Erskine Sandstone is probably Lower Triassic in age (B. E. Balme, personal communication). Both the Blina Shale and the Erskine Sandstone, therefore, probably belong in the Lower Triassic rather than the Upper Triassic as suggested by Brunnschweiler.

At The Sisters Plateau plant locality the Erskine Sandstone is a quartzose, micaceous, carbonaceous, grey, thin-bedded silty sandstone. Pieces of plant stems are commonly preserved with rare leaf impressions. Both were collected.

Eighty-one measurements of the attitudes of cross-beddings in the Erskine Sandstone at Erskine Range were made and the poles of the measurements later plotted on a polar equal-area net. It can be inferred from the plot that the ancient river responsible for the deposition of the Erskine Sandstone flowed northwards in this area (Fig. 2).

Environment of Deposition of the Blina Shale

Brunnschweiler (1954) has suggested that the environment of the Blina Shale may be described as "lagoonal or in parts estuarine". It is diffi-

cult to reconcile the evidence with either of these postulates.

Shoreline lagoons are generally linear and fronted by barrier bars or beaches. Currents sweep through them so that channels and flats within the lagoon are well defined, linear and broadly parallel to the shoreline. The outcrop pattern of the Blina Shale, however, is not linear but indicates that the environment was basinal. The lithology of the formation is remarkably uniform both laterally and vertically. No evidence is known for the presence of intraformational, contemporaneous bars and/or beaches. It is unlikely that the facies was lagoonal in the strict sense.

In estuarine environments the sea dominates, i.e., tidal currents are more effective than river currents in distributing the accumulated sediment. Channels and flats form but are con-

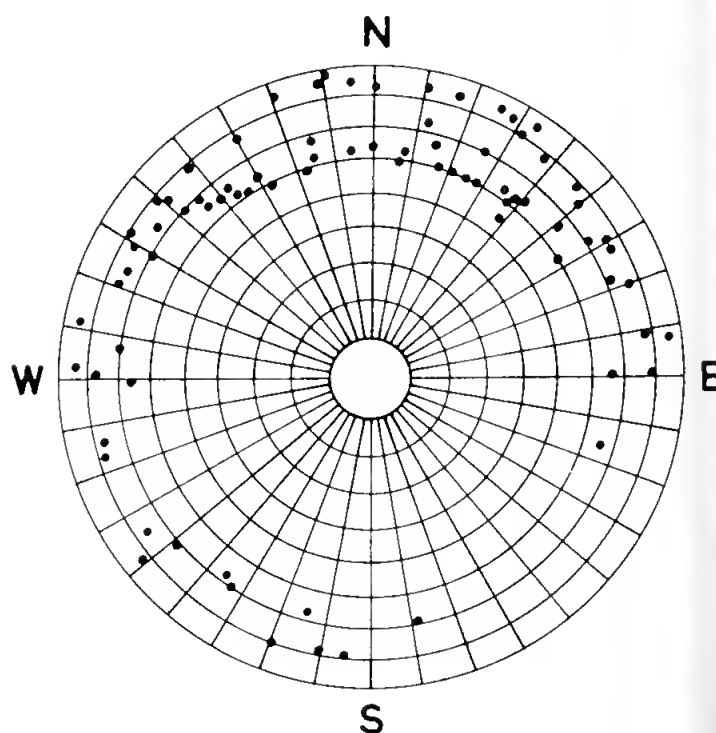


Fig. 2.—Poles of eighty-one cross-beddings in the Erskine Sandstone at Erskine Range plotted on a polar equal area net.

stantly reworked. It is difficult to envisage the *Isaura* equinoidal beds developing, and entire jaws of vertebrate animals being preserved, in an environment as active as the river estuary.

The author considers that the Blina Shale was deposited, during a period of intermittent subsidence, in a wide, shallow, gently shelving, quiet gulf or sea into which protruded the delta of a major river. The beds exposed at Erskine Range were probably deposited near-shore on the subaqueous topset plain of this delta.

The high iron content of the sediment is indicated by the iron-rich leaching structures in all stages of development, by the reddish streak of yellow and buff-coloured oxidised beds, by bands of nodular ironstone, and by the blue-grey colour of the fresh rock which probably derives from its ferrous iron content. It is highly likely that these iron-rich sediments

were ferruginous in origin, their iron content resulting from the breakdown of rocks through subaerial weathering. This indicates near-shore deposition.

The grade of the sediments constituting the Blina Shale at Erskine Range (almost invariably very fine-grained to silty), their shape (sub-angular), their degree of sorting (moderate) and the high percentage of quartz point to comparatively near-shore deposition with a fairly rapid inflow.

Shallow-water deposition best explains the linear ripple marks exposed at Locality 8 where several entire lower jaws of fossil amphibians were quarried from the ripple-marked surface.

Features such as thin-bedding, lamination, cross-lamination and colour-variegation between laminae are visible on weathered surfaces. Such features are known to characterise present-day deltaic environments (Shepard and Lankford 1959).

It may be expected that silt banks were built up in front of the delta shoreface to the point where they became exposed. The several thin discontinuous bands of ferruginised, purplish siltstone, that occur in the sequence examined may well express this phase of the sedimentation cycle. Their subsequent overlap by blue-grey silts indicates that subsidence was intermittent during deposition of the Blina Shale.

Balme considers that the richness of the microplankton suite and spore-pollen assemblages suggests a shallow-water near-shore marine environment of deposition for the Blina Shale (B. E. Balme, personal communication). His data came from various bores in the Fitzroy Trough, the nearest of which is about nineteen miles north of Erskine Range. The general lithology of the Blina Shale in these bores, however, is similar to that exposed in the same formation at Erskine Range and the evidence from Balme's data may usefully be correlated with the palaeoecological implications of the fauna and flora collected at Erskine Range.

The presence of only occasional plant fossils in the Blina Shale at Erskine Range suggests near-shore marine deposition as opposed to deposition in a vegetated shoreline swamp or lagoon with vegetated shores.

The faunal assemblage at Erskine Range is of especial significance in determining the environment. Thin, coquinoïdal beds of *Isaura* are associated with occasional shells of *Lingula*, with the remains of presumably continental fossil amphibians and with fish remains. *Isaura* has fresh-water and brackish-water affinities (Piveteau 1953) while *Lingula* is a marine mud-dweller of wide tolerances. Assuming the ancient amphibians were continental, they may have lived on the subaerial delta and their remains could have been carried downstream, not necessarily any great distance, accumulating on the subaqueous topset plain and in inshore pockets once they reached the sea. This could explain why no entire vertebrate animals were found, although occasional articulated remains were

collected. Dipnoan teeth were among the identifiable fish remains. Living descendants of these ancient fish are exclusively fresh-water.

The sedimentary characters of the Blina Shale, the presence of only occasional plant remains, although these are usually well preserved, the microplankton suite and the occurrence of *Lingula* indicate that the formation accumulated by deposition on the topset plain of the marine delta of a major river. But the rare articulated remains of the vertebrate fauna with its fresh-water affinities and the *Isaura* fauna, present certain anomalous features which only further work can clarify. It is noted, however, that *Isaura* has marine associations in the Upper Triassic of Germany, and that trematosaurid amphibians occur together with ammonites in the marine Lower Triassic of Greenland (Termier and Termier 1960).

The period of intermittent subsidence during which the Blina Shale was deposited gradually gave way to a regressive phase in which the marine deltaic beds of the Blina Shale at Erskine Range were overlapped by the sandier, cross-bedded, river channel sediments of the Erskine Sandstone with its rich flora. The disconformity between the Blina Shale and the Erskine Sandstone represents the transitional period between these transgressive and regressive phases.

Conclusion

It is hoped that the interest aroused by the joint Museum expedition to the Fitzroy Trough will stimulate further work on this important Triassic unit, the Blina Shale. Balme has recognised a probable equivalent to the Blina Shale in B.M.R. Wallal 44A Bore in the southern part of the Canning Basin where no Triassic has previously been recorded (B. E. Balme, personal communication). Triassic rocks in the Canning Basin, therefore, have a much wider distribution than was hitherto thought.

The importance of this Triassic vertebrate assemblage in the Australian record, with the opportunities it affords for correlation on a world-wide scale, cannot be too highly stressed.

The vertebrate localities have scarcely been touched and good collections will undoubtedly reward future search. One of the objectives of this paper has been to give descriptions of the localities from which vertebrate fossils were obtained by the expedition and to direct future searchers to the most rewarding exposures so that valuable field time is not wasted in un-rewarding areas.

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11.—Contributions to the Knowledge of Western Australian Gramineae

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Twenty-one species, including two introductions, are recorded for the first time. Four records are confirmed. Supplementary records for a further twenty-six rarely collected or recently described species and notes on taxonomy and distribution are included.

Introduction

Much of the knowledge of West Australian grasses has resulted from a comprehensive account of the family by Gardner (1952). These additions from the Kimberley District are based on collections by Miss N. T. Burbidge, Division of Plant Industry, C.S.I.R.O., Canberra, made during seed collecting visits in April, 1956 and 1958, Mr. E. C. B. Langfield, Division of Land Research and Regional Survey, Kimberley Research Station, C.S.I.R.O., and Mr. D. W. Rust, owner of Karunjie Station, East Kimberleys. Also, surveys conducted by the Division of Land Research and Regional Survey, C.S.I.R.O. in various parts of the Kimberleys during the dry seasons of 1949, 1952, 1954 and 1959 and wet season collections by the author in 1955 yielded further material.

The original specimens of all cited collections are located in the herbaria of the C.S.I.R.O., Canberra. The herbaria to which duplicates have been donated are indicated after the citations or, if one or more institutions have received duplicates of several collections of a species, at the end of a series of citations. The abbreviations used are those given in the Index Herbariorum ed. 4 (1959).

New Records

The following species are given as new records for Western Australia.

Aristida capillifolia Henr., Meded. Herb. Leid. 2:298 (1932).

New York Pool, 35 miles N.E. of Karunjie Station, among boulders on sandstone scarp near waterfall, *Lazarides* 3088, 29.vi.1952 (CANB, BRI, NT, NSW, MEL, AD, PERTH, K, US); Durack Range, 8.5 miles S.E. of Bedford Downs Station, occasional in small stony creek in gorge of sandstone range, *Lazarides* 6386, 21.vii.1959 (CANB).

Previously recorded from Central Australia and northern South Australia, and recently collected in the Northern Territory: an uncommon species, largely confined to very rocky habitats of sandstone or quartzite. Diagnostic characters include the following: slender culms, narrow leaves and lemmas, slender awns, furrowed scabrous lemmas, lateral awns slightly shorter than the medians, fastigiate branched culms, and scanty linear panicles.

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Aristida hirta Domin, Bibl. Bot. 85:339 (1915). Karunjie Station, on sandy soil, *Rust* 95, 7.iii.1950 (CANB).

A rarely occurring species previously recorded only from northern Queensland and since collected in the Northern Territory.

The species belongs in the section *Arthratherum* Henrard and shares with *A. superpendens* Domin the distinction of possessing long, strongly recurved central awns stouter than the laterals. From that species, however, *Aristida hirta* may be distinguished by its hairy (not scaberulous) culm and glabrous (not pubescent) collar.

Dichanthium aristatum (Poir.) C. E. Hubbard. Kew Bull. 1939:654 (1939). *Andropogon aristatum* Poir., Encyc. Suppl. 1:585 (1810).

Kimberley Research Station, occasional on grey heavy-textured soil, *Lazarides* 5022, 20.ix.1954 (CANB, BRI, NT, K, US).

Apparently of recent introduction in Western Australia: naturalised and widespread in Queensland. The dense patch of long hairs on the uppermost internode near the base of the inflorescence is unique among the Australian species.

Digitaria erirolepis Henr., Monogr. Gen. Digitaria, 819 (1950).

Nine miles N.E. of Kalumburu Mission, occasional in sandy creek-bed, *Lazarides* 4900B, 3.ix.1954 (CANB).

Only the type collection from northern Queensland previously recorded. The densely hairy spikelets with long, verrucose hairs are distinctive.

Digitaria gibbosa (R.Br.) Beauv., Agrost. 160 (1812). *Panicum gibbosum* R.Br., Prod. 193 (1810).

Six miles S.W. of Denham River Station, dominant in patches in deep yellow sand with *Eucalyptus grandifolia*, *Lazarides* 5045, 15.iv.1955 (CANB, BRI, NT, NSW, MEL, AD, PERTH, K, US).

Commonly known from northern areas in Queensland and the Northern Territory. A slender annual species with solitary, linear racemes and characteristic spikelets; the spikelets are swollen at the base and become strongly gibbous with maturity; the lower lemmas are long ciliate on the margins, the hairs becoming firmly horizontal.

Digitaria papposa (R.Br.) Beauv., Agrost. 160 (1812). *Panicum papposum* R.Br., Prod. 192 (1810).

Spring Creek, Button's Gap, Ord River, sandy bank of creek, *Burbidge* 5693, 10.iv.1958 (CANB).

Previously recorded only from islands in the Gulf of Carpentaria on the coast of Arnhem Land, Northern Territory. The species also occurs in northern Queensland. It is a tufted perennial with a pubescent root-base and the following diagnostic characters: spreading panicle with long racemes (up to 20 cm) which are whorled at the lower nodes and gradually become solitary upwards, densely and long hairy spikelets scattered along the racemes, slender usually elongated pedicels, and absent lower glume.

Digitaria robusta Hughes, Kew Bull. 1923:310 (1923).

Kimberley Research Station, *Langfield* 201, 14.ii.1950 (CANB).

Only the type collection from Melville Island, Northern Territory previously recorded. The species has since been collected in northern Queensland. Both the pedicelled and sessile spikelets bear sub-marginal bristles on the lower lemma in contrast to *D. etenantha* (F. Muell.) Hughes, its closest affinity, in which the rigid bristles are absent from the sessile spikelet.

Eragrostis cumingii Steud., Syn. Pl. Glum. 1:266 (1854). *Eragrostis bleeseri* Pilger, Notizbl. Bot. Gart. Berlin 10:112 (1927).

Karunjie Station, on levee soil in irrigation plot, *Lazarides* 3144, 30.vi.1952 (CANB, BRI); Button's Gap, Ord River, Kimberley, silt near water course, *Burbidge* 5199, 17.iv.1956 and 5698, 10.iv.1958 (CANB).

The only previous Australian records comprise one record from Central Australia and Pilger's collection from the Northern Territory (Darwin). However, the species is common throughout Northern Australia and Malaysia. It is a slender, somewhat variable, annual which may be recognized by the following combination of characters: spikelets usually clustered on short branches in an interrupted panicle, lemmas granular with the lateral veins slightly nearer to the margins than to the midnerves, and palea ciliate on the keels with long, stiff hairs.

Steudel's name is based on Cuming's collections from the Philippine Islands which, according to information collected at Kew by Miss N. T. Burbidge, differ only slightly from Pilger's species.

Eragrostis tenax Jedw., Bot. Archiv 5:193 (1924).

Edkins River, 12 miles N.W. of Glenroy Meatworks, common on sandy river bank, *Lazarides* 5153, 22.iv.1955 (CANB, BRI, NSW, MEL, AD, PERTH, K, US).

Only the original collection from the Northern Territory previously recorded, but fairly common throughout northern Australia. It is a perennial species with distinctive terminal and axillary panicles, the latter in dense sessile clusters at the upper nodes, sometimes also a few enclosed in the basal leaf-sheaths.

Eriachne avenacca R.Br., Prod. 184 (1810).

19 miles S.E. of Kimberley Research Station, on deep sands with *Eucalyptus tetradonta* and *Sorghum* spp., *Perry* and *Lazarides* 2663, 31.vi.

1949; 25 miles N.E. of Karunjie Station, in lateritic yellow sandy soil, *Lazarides* 3090, 29.vi.1952 (CANB, BRI, NT, NSW, MEL, AD, PERTH, K, US); 74 miles S.W. of Kalumburu Mission, common in yellow gravelly podsollic soil with *Eucalyptus latifolia* and *Melaleuca* spp., *Lazarides* 4947, 6.ix.1954 (CANB, BRI, NT, NSW, MEL, AD, K, US); 0.5 mile S.W. of Bedford Downs Station, common in patches in skeletal soil with *Eucalyptus brevifolia* open woodland, *Lazarides* 5076, 17.iv.1955 (CANB, BRI, NSW, MEL, AD, PERTH, K, US).

Previously known from far northern areas in Queensland and the Northern Territory. The prominently 10-13-nerved glumes and long-acuminate (sometimes shortly awned) lemmas are characteristic.

Eriachne rara R.Br., Prod. 183 (1810).

Nine miles N.E. of Kalumburu Mission, in creek-bed but also common on deep red and yellow sands, *Lazarides* 4900A, 3.ix.1954 (CANB, BRI, NT, NSW, K, US).

Previously recorded from Queensland and the Northern Territory, mainly from near-coastal or insular districts. The plants have loose panicles, awned ciliate lemmas (the awns usually 10-15 mm long), and the glumes are glabrous or more often fringed along the margins with tubercle-based hairs.

Eriachne squarrosa R.Br., Prod. 183 (1810).

Karunjie Station, *Rust* 100, 7.iii.1950; Kimberley Research Station, *Langfield* 286, 1.iii.1952; Thompson's Springs, East Kimberley, on sandy soil, *Langfield* 345, 25.vii.1954 (CANB).

Previously known from the Northern Territory, northern Queensland, and New Guinea. Usually a perennial, the species may be recognised by its fairly tall habit, long awns (2-4.5 cm) on the lemmas, distinctly bifid palea, and densely hispid glumes.

Iseilema ciliatum C. E. Hubbard, Hook. Ic. Pl. 33:t.3286, 6 (1935).

Near Mt. House Station, common on heavy-textured gilgaied soil with *Astrelba squarrosa* grassland and sparse *Bauhinia cunninghamii*, *Lazarides* 5158, 23.iv.1955 and 5167, 24.iv.1955 (CANB, BRI, NT, NSW, MEL, AD, PERTH, K, US).

Previously recorded only from the type locality (Mt. Walker) in northern Queensland; a solitary specimen has since been collected in the Northern Territory. The species is a coarse annual and distinctive within the genus by the following characters: lower glume of the involucre densely ciliate on the keels, scaberulous and deeply grooved on the back; margins of the leaves particularly near the base with scattered, long, slender, tubercle-based hairs.

Iseilema dolichotrichum C. E. Hubbard, Hook. Ic. Pl. 33:t.3285 (1935).

16 miles S.W. of Lamboo Station, dominant in small patches on skeletal slopes of low quartzitic hill with *Eucalyptus brevifolia*—*Triodia intermedia* open woodland, *Lazarides* 6322A, 13.vii.1959 (CANB); 8.5 miles W.N.W. of Mt. Amherst Station, common on stony patches in

Triodia wiseana—*T. intermedia* grassland, *Lazarides* 6349, 16.vii.1959 (CANB, BRI, NSW, MEL, AD, PERTH, K).

The only previous records comprise the type specimen from Duchess in Queensland and a single collection from Central Australia.

The species is one of the very few of the Australian representatives not confined to heavy soil grassland plains. It differs from the majority of *Iseilema* species in the very long basal hairs (up to 6 mm) of the racemes and from *I. eremaeum* S. T. Blake, its closest affinity, in the closely glandular keels of the spathes.

Iseilema windersii C. E. Hubbard, Hook. Ic. Pl. 33:t.3284 (1935).

Kimberley Research Station, on sandy loam, *Langfield* 66, 19.iii.1949 (CANB).

Previously recorded from Queensland, where it is common on heavy soil grassland plains of northern, western, and central-western districts, and Central Australia; also occurs in the Northern Territory. The species is allied to *I. ciliatum* but differs in the evenly pubescent lower glume of the involucre spikelet and absence of hairs on the margins of the leaves. The keels of the spathes are usually closely glandular and plants in the living state are often strongly aromatic.

Panicum seminudum Domin., Bibl. Bot. 85:320 (1915).

Point Springs, 24 miles N.E. of Carlton Station, East Kimberleys, sandy soil, *Langfield* 396 (CANB).

Originally described from northern Queensland (Yarraba) and recorded from the Northern Territory. The long lower glume (as long as the spikelet) is very distinctive. Its closest affinity is *Panicum delicatum* Hughes from which it differs in the larger spikelets (3.5 mm long).

Panicum trachyrhachis Benth., Fl. Aust. 7:490 (1878).

72 miles N.N.W. of Gibb River Station, common in floodout area of small creek on grey heavy-textured soil with *Arundinella nepalensis*, *Lazarides* 4961, 7.ix.1954 (CANB, BRI, NT).

Northern Territory and Queensland, mainly from near-coastal districts or higher rainfall areas of the interior.

Usually associated with watercourses and areas of periodic inundation where heights of six feet are commonly attained. The species is a robust tufted perennial with a spreading decompound panicle, scabrous panicle branches, acuminate lower glume as long as the spikelet and scaberulous on the tip, and broad (up to 2.5 cm) often tuberculate leaf sheaths.

Pseudopogonatherum irritans (R.Br.) A. Camus, Ann. Soc. Linn. Lyon, n.s., 68:205 (1922). *Saccharum irritans* R.Br., Prod. 203 (1810). *Pollinia irritans* (R.Br.) Benth., Fl. Aust. 7:525 (1878).

55 miles S.W. of Kalumburu Mission, dominant in patches near water, also common in sandy seepage areas, *Lazarides* 4940, 6.ix.1954 (CANB).

Higher rainfall or coastal districts of the Northern Territory and Queensland, and New Guinea.

The species is distinctive by virtue of its biennial or perennial habit, larger spikelets, and longer denser spikes as compared with the other Australian representative *P. contortum*, an inland annual of Queensland and the Northern Territory.

Setaria apiculata (Scribn. & Merr.) K. Schum., Just's Jahresb. 28 (1): 417 (1900). *Chaetochloa apiculata* Scribn. & Merr., U.S. Dep. Agric. Bull. Agrost. 21:9 (1897).

Karunjie Station, on levee soil, *Lazarides* 3143, 30.vii.1952 (CANB, BRI, NT, NSW, MEL, AD, PERTH, K, US); 55 miles S.W. of Kalumburu Mission, common on sandy creek-banks and in depressions, *Lazarides* 4938, 6.ix.1954 (CANB, BRI, NT, K); 19 miles S.E. of Tableland Station, occasional on sandy levee soil with *Aristida hygrometrica* and *Eucalyptus papuana*, *Lazarides* 5108, 18.iv.1955 (CANB, BRI).

Apparently somewhat rare; previously known from Queensland and the Northern Territory. The broadly ovate spikelets are distinctive within the Australian representatives.

Sorghum verticilliflorum (Steud.) Stapf in Prain, Fl. Trop. Afr. 9:116 (1917). *Andropogon verticilliflorus* Steud., Syn. Pl. Glum. 1:393 (1854).

Fossil Downs Station, associated with *Sorghum sudanense* in irrigation plot, *Lazarides* 3135, 2. vii. 1952 (CANB, BRI).

A native of Africa; of recent introduction in Western Australia and New South Wales, but naturalised and widespread in Queensland, the species is allied to *Sorghum sudanense* and *S. halepense* but differs from the former in its perennial habit and stout culms and from the latter in the absence of rhizomes.

Triodia inutilis N. T. Burbidge, Aust. J. Bot. 1 (1): 163 (1953).

4 miles S. of Texas Downs Station, dominant on skeletal soil on shales with *Eucalyptus pruinosa*, *Lazarides* 3177, 14.vii.1952 (CANB, BRI, NT, NSW, K, US); 19 miles S.W. of Halls Creek Township, dominant on skeletal hill slopes on metamorphic rocks, *Lazarides* 6351, 16.vii.1959 (CANB, BRI, NT, NSW, MEL, AD, PERTH, K, US).

Though not far removed from the type locality (Wave Hill) and the species' apparent centre of concentration in the Northern Territory, the above collections represent the western extremity of its known distribution.

The long, slender, drooping leaves and densely woolly sheaths are helpful field characteristics.

Confirmed Records

Chloris barbata (L.) Sw., Fl. Ind. Occid. 1:200 (1797). *Andropogon barbatus* L., Pl. Jam. Pugill. 30 (1759).

Kimberley Research Station, on river levee, *Langfield* 22; 202, 14.ii.1950; and 338, 30.viii.1953 (CANB).

Confirmed record for Western Australia; recorded by Gardner (1930, p. 11) and Specht (1958, p. 197), but later omitted by Gardner (1952). A widespread weed in the tropics of both hemispheres.

Ectrosia leporina R. Br., Prod. 186 (1810) var. **leporina** C. E. Hubbard, Hook. Ic. Pl. 34:t. 3312, 11 (1936).

55 miles S.W. of Kalumburu Mission, common in seepage area on sandy podsollic soil, *Lazarides* 4942, 6.ix.1954 (CANB, BRI, NT); 63 miles S.W. of Kalumburu Mission, dominant in broad shallow depression with *Alloteropsis semialata* and *Eucalyptus apodophylla*, *Lazarides* 4944, 6.ix. 1954 (CANB); 72 miles N.N.W. of Gibb River Station, common in sandy depressions, *Lazarides* 4963, 7.ix.1954 (CANB, BRI, NT); Karunjie Station, *Rust*, without number (CANB).

Confirmed record for Western Australia. Though listed by Gardner (1930, p. 10), the species was later omitted (Gardner 1952).

Widespread: northern areas of the Northern Territory, throughout Queensland, northern interior of New South Wales, and New Guinea. A perennial species which invariably grows in dense colonies over small areas. Panicles are dense and spike-like with short spikelets (usually 3-5 mm long) and smooth lemmas.

Paspalidium distans (Trin.) Hughes, Kew Bull. 1923:317 (1923). *Panicum distans* Trin., Sp. Gram. t.172 (1829).

50 miles S.S.E. of Kalumburu Mission, occasional in sandy creek-bed with *Elytrophorus spicatus*, *Lazarides* 4849, 1.ix.1954 (CANB).

Confirmed record for Western Australia; not mentioned by Gardner (1930, 1952), but recorded for "Kimberley, W.A." by Specht (1958). A widely distributed but erratically occurring species largely confined in Australia to higher rainfall or sub-coastal areas of the Northern Territory and Queensland; also known from New Guinea. It is a slender perennial with the following characteristics:— spikelets mostly biseriate in short, usually simple racemes; lower racemes interrupted along the main axis; upper glume shorter than the spikelet and exposing the transversely rugose upper lemma.

Pennisetum arnhemicum F. Muell., Fragm. Phyt. Aust. 8:109 (1873).

7 miles E. of Denham River Station on steep rocky volcanic slopes with *Eucalyptus brevifolia* and *Triodia* sp., *Perry* and *Lazarides* 2526, 19.vii. 1949 (CANB, BRI, NSW, MEL, AD, PERTH, NT, K, US); Winjinna Gorge, 41 miles S.E. of Napier Downs Station, amongst limestone boulders at base of Napier Range, *Lazarides* 3127, 25.vi.1952 (CANB, BRI, NT, NSW, MEL, K, US); 10 miles N.W. of Elgie Cliffs Station, occasional in skeletal sand amongst sandstone boulders, *Lazarides* 5095, 17.iv.1955 (CANB, BRI, NT, K, US); near Mt. House Station, common in rocky gorges and creeks on slopes of Mt. House with *Sorghum australiense* and *Pseudochaetochloa australiensis*, *Lazarides* 6442, 27.vii.1959 (CANB).

Confirmed record for Western Australia; recorded by Fitzgerald (1918, p. 114) and Gardner (1930) but later omitted (Gardner 1952).

Not uncommon in mountainous regions usually in habitats with better water relations and invariably in association with the rarely col-

lected *Pseudochaetochloa australiensis*; previously known from tropical areas of Queensland and the Northern Territory. The spike appears densely woolly due to the plumose involucreal bristles.

Supplementary Records

The following citations and notes are supplementary to existing scanty records.

Alloteropsis semialata (R. Br.) Hitchc., Contr. U.S. Nat. Herb. 12:210 (1909). *Panicum semialatum* R. Br., Prod. 192 (1810).

32 miles S.S.E. of Kalumburu Mission, occasional in grey heavy-textured soil, *Lazarides* 4877, 1.ix.1954 (CANB). Also observed 63 miles S.W. of Kalumburu Mission in association with *Ectrosia leporina*.

Only one previous record from Western Australia but widely distributed elsewhere:— northern areas of the Northern Territory, throughout Queensland, New South Wales, Malaysia. It differs from the other Australian species, *A. cimicina* (Retz.) Stapf, in its perennial habit and fibrous, woolly root-base.

Brachiaria ramosa (L.) Stapf in Prain, Fl. Trop. Afr. 9:542 (1919). *Panicum ramosum* L., Mant. 1:29 (1767).—var. **grandiflora** Hughes, Kew Bull. 1923:315 (1923).

Kimberley Research Station, *Langfield* 241, 27.i.1952 (CANB); 50 miles S.S.E. of Kalumburu Mission, occasional in sandy creek bed with annual grasses, *Lazarides* 4851, 1.ix.1954 (CANB, BRI, NT, NSW, K, US).

The only previous records comprise two collections from the Northern Territory and one from the Kimberleys; also occurs in Queensland. The species may be recognised by its semi-prostrate habit, broad pubescent leaves, several spreading racemes, and numerous evenly pubescent spikelets.

Brachiaria reptans (L.) C. A. Gardner & C. E. Hubbard, Hook. Ic. Pl. 34:t.3363, 3 (1938). *Panicum reptans* L., Syst. Nat. ed. 10, 2:870 (1759).

Ord River, 69 miles S. of Kimberley Research Station, on river bank, *Lazarides* 2963, 11.vii. 1952 (CANB, BRI); Kimberley Research Station, on sandy loam, *Langfield* 38, 13.i.1949, 75, 4.iii. 1949, and 153, 14.ii.1950 (CANB).

Only one previous Western Australian record but known from the Northern Territory and Queensland and widespread in the tropics of both hemispheres. The spikelets are the smallest (1.5 mm long) among the Australian species.

Chloris pumilio R. Br., Prod. 186 (1810).

10 miles S.E. of Mt. House Station, codominant with *Eriachne glauca* on creek banks and in depressions, *Lazarides* 5157, 22.iv.1955 (CANB, BRI, NT, SW, MEL, AD, PERTH, K, US).

An uncommon species previously known from northern Queensland, coastal areas of the Northern Territory, and from one collection in the Kimberleys. The species is allied to *C. ruderalis* Domin but differs in the sub-equal (not distinctly unequal) awns of the lemma.

Chrysopogon latifolius S. T. Blake, Univ. Qd Papers, Dep. Biol. 2(3):7 (1944).

42 miles S.S.E. of Kalumburu Mission, common in red gravelly soil with *Eucalyptus tectifica* and *Sorghum australiense*, *Lazarides* 4868, 1.ix.1954 (CANB); 32 miles S.S.E. of Kalumburu Mission, occasional in grey heavy textured soil, *Lazarides* 4876, 1.ix.1954 (CANB, BRI, NT); 16 miles S.E. of Mt. House Station, dominant on creek bank with *Eriachne* spp., *Lazarides* 5156, 22.iv.1955 (CANB, BRI, NT, K).

Previously known from two Kimberley collections and the Northern Territory but not common in the latter area. The species occurs on a wide range of soils and habitats but invariably near permanent streams. The broad, flat, many-nerved leaves and the numerous panicle-branches in each whorl are distinctive features.

Echinochloa stagnina (Retz.) Beauv., Agrost. 161 (1812). *Panicum stagninum* Retz., Obs. 5:17 (1789).

"The Razorbacks" near 65 m. peg on Wyndham-Darwin road, swamps on heavy grey clay, *Burbidge* 5185, 17.iv.1956 (CANB).

First recorded only recently for Australia as well as for Western Australia and Queensland by Blake (1952, p. 91) from two collections. This is the third collection. The species is considered a weed in rice-growing projects of northern Australia.

Eriachne fastigiata Lazar., J. Roy. Soc. W. Aust. 42(2):33 (1959).

Based on two collections from the Kimberleys (Glenroy). From observations made during the 1959 field season, the species is common in the Glenroy-Tableland-Napier Downs area and confined almost wholly to shallow soils developed on shales.

Eriachne festucacea F. Muell., Fragm. Phyt. Aust. 5:205 (1866).

31 miles S.E. of Kimberley Research Station, in small rocky creek in dissected quartzite area, *Lazarides* 2664, 31.vii.1949 (CANB, BRI, NT, NSW, MEL, AD, K, US); 50 miles S.S.E. of Kalumburu Mission, dominating rocky creek beds in hilly volcanic area, *Lazarides* 4848, 1.ix.1954 (CANB, BRI, NT, NSW, MEL, AD, PERTH, K, US); 9 miles N.W. of Elgie Cliffs Station, dominating sandy or rocky river beds, *Lazarides* 5092, 17.iv.1955 (CANB, BRI, NT).

Confined to the Kimberley District and adjacent parts of the Northern Territory. The widely-divergent lemmas and paleas, glabrous glaucous culms, convolute leaves, and broad leaf-sheaths abruptly contracted at the ligule are important diagnostic characters; a characteristic species in beds of permanent streams.

Heterachne gulliveri Benth., Hook. Ic. Pl. 13: 39, t. 1250 (1877).

8 miles S.E. of Tableland Station, common in sandy depressions with *Aristida hygrometrica*, *Lazarides* 5120, 18.iv.1955 (CANB, BRI, NT).

A selective species of sandy habitats with good water relations; previously known from northern Queensland and just beyond the border in the north-eastern corner of the Northern Territory and from one locality in Western Australia. The spikelets are the

smallest (2-2.5 mm long and wide) within the genus. Other distinctive characters include narrow interrupted panicles, orbicular spikelets, and ciliate lemmas and paleas.

Isiclema filipes S. T. Blake, Univ. Qd Papers, Dep. Biol. 2(3):60 (1944).

16 miles S. of Kalumburu Mission, common in heavy volcanic soil and nearby stony creeks, *Lazarides* 4969, 9.ix.1954; 64 miles S. of Kalumburu Mission, common throughout volcanic areas in rocky creek beds, *Lazarides* 4838, 31.viii.1954 (CANB).

Previously known only from the type collection. The elongated, slender peduncles (3-4.5 cm long) are unique within the genus.

Panicum pauciflorum R. Br., Prodr. 191 (1810).

4 miles N.W. of Elgie Cliffs Station, occasional on rock quartzite slopes with *Plectrachne pungens*, *Lazarides* 6391, 21.vii.1959 (perennial form) (CANB).

Previously recorded (*Lazarides* 1959 p. 338) in Western Australia from only two localities. The above locality represents the western extremity of the species present distribution range; known also from the Northern Territory and Queensland.

Plectrachne bynoei C. E. Hubbard, Kew Bull. 1: 30 (1941).

Thompson's Springs, 42 miles S.E. of Kimberley Research Station, on steep rocky cliff, *Lazarides* 2945, 10.vii.1952 (CANB, BRI, PERTH, K); Martin's Gap, E. of Ord River, western slope of rocky hill, *Burbidge* 5137, 14.iv.1956 (CANB).

Though rarely collected previously, the species is common on rugged, sandstone slopes of major mountain systems such as the Durack and Carr Boyd Ranges. The single-awned lowest lemmas are unique within the genus. No previous mention has been made of the extremely resinous, shiny leaf-blades and sheaths, a character prominently evident on *Lazarides* 2945, and the glumes of all collections seen are much shorter (less than 5 mm) than that given in previous descriptions. Only the type collection from the Kimberleys previously recorded but since collected in adjacent parts of the Northern Territory.

Plectrachne schinzii Henr., Vierteljahrsschr. Nat. Ges. Zurich 62:132 (1929).

5 miles S.E. of Gordon Downs Station, on deep sandy soil with *Acacia* spp. and *Plectrachne* spp., *Perry* and *Lazarides* 2470, 14.vii.1949 (CANB, BRI, NT, K, US); 9 miles S.W. of Oobagooma Station, common on sand dunes on edge of salt marsh, *Lazarides* 3124, 22.vi.1952 (CANB, BRI, NT).

The latter locality is well north of previous Western Australian records. The species is well developed in northern Central Australia with isolated occurrences in the Northern Territory as far north as Victoria River Downs Station.

Pseudochaetochloa australiensis Hitchc., J. Wash. Acad. Sci. 14:492 (1924).

Terroni Gorge, 10 miles N.W. of Elgie Cliffs Station, occasional in skeletal sand amongst sandstone boulders, *Lazarides* 5096, 17.iv.1955

(CANB, BRI, NT, NSW, MEL, AD, PERTH, K, US); Durack Range, 8.5 miles S.E. of Bedford Downs Station, common in stony creek from gorge in sandstone range with *Pennisetum arnhemium* and dense mixed vegetation, *Lazarides* 6383, 21.vii.1959 (CANB, BRI, NSW, MEL, PERTH, K, US).

Previously recorded from only two Kimberley collections. However, the species is not uncommon in better watered, rocky habitats of rugged, usually sandstone mountain systems. Both cited collections possess only male florets.

Sacciolepis indica (L.) Chase, Proc. Biol. Soc. Wash. 21:8 (1908). *Panicum indicum* L., Mant. 2:184 (1771).

2 miles N. of Gibb River Station, common near spring in sandy soil with *Ischaemum* spp., *Lazarides* 4988, 11.ix.1954 (CANB); 6 miles W. of Tableland Station, common in deep sand near small creek with mixed forbs and grasses, *Lazarides* 6407, 22.vii.1959 (CANB, PERTH, US).

Only one previous record from Western Australia, but widespread elsewhere: northern Australia, throughout Queensland, coastal New South Wales, New Guinea; confined to water-courses or similar situations.

Sacciolepis myosuroides (R. Br.) A. Camus in Lecomte, Fl. Gen. Indo-Chine 7:460 (1922). *Panicum myosuroides* R. Br., Prod. 189 (1810).

55 miles S.W. of Kalumburu Mission, common in sandy seepage area, *Lazarides* 4943, 6.ix. 1954 (CANB, BRI, NT).

Widespread throughout tropical Australia in similar habitats as the above species but usually less common; also known from New Guinea, tropical Asia, and Africa. It differs from the only other Australian representative in the smaller (1 mm long), more rounded, blunter spikelets. Both species are slender annuals with dense, spiciform panicles which may be elongated to 9 cm in *S. indica*, and to 15 cm in *S. myosuroides*.

Sclerandrium truncatiglume (Benth.) Stapf et C.E. Hubbard, Hook. Ic. Pl. 33:t. 3262 (1935). *Ischaemum truncatiglume* F. Muell. ex Benth., Fl. Aust. 7:518 (1878).

Carson River, 38 miles S.S.E. of Kalumburu Mission, common on sandy river bank near water, *Lazarides* 4869, 1.ix.1954 (CANB, BRI, NT, K); Thompson's Springs, 42 miles S.E. of Kimberley Research Station, *Lazarides* 3136, 6.vii.1952 (CANB, BRI, NT, NSW, MEL, AD, PERTH, K, US).

Previously known from isolated occurrences in the Kimberleys and the Northern Territory; the species has a disjunct distribution in the higher rainfall tropics of northern Australia and extends to New Guinea. The species, a tussocky perennial 90-130 cm high with 3-6 fascicled, spiciform, brown racemes, is invariably associated with permanent surface waters.

Thaumastochloa pubescens (Domin) C.E. Hubbard, Hook. Ic. Pl. 34:t.3313 (1936). *Ophiuros pubescens* Domin, Bibl. Bot. 85:262 (1915).

Karunjie Station, *Rust* 33, 1.iii.1950; near Kimberley Research Station, open gully in sandstone cuterop, *Burbidge* 5712 and, open ground

under savannah near sandstone ridge, 5719, 12.iv.1958 (CANB).

The only Western Australian record is based on fragmentary material; also known from the Northern Territory and Queensland. The species has affinities with *T. constricta* S. T. Blake but differs in the rugose or tuberculate lower glumes and glabrous, smooth, less constricted internodes of the spike.

Thaumastochloa rariflora (F. M. Bail.) C. E. Hubbard, Hook. Ic. Pl. 34:t.3313 (1936). *Rottboellia rariflora* F. M. Bail., Qd Dep. Agric. Bot. Bull. No. 8: 86 (1893).

11 miles N.E. of Tableland Station, common in deep yellow sands with *Eucalyptus ferruginea* and *Aristida hygrometrica*, *Lazarides* 6404, 22.vii. 1959 (CANB).

Only one previous record from Western Australia and rarely collected in the Northern Territory, but commonly known from northern Queensland. The curved, elongated peduncles (up to 7 cm long), reduced spikes of 1-2 spikelets, and smooth lower glume are diagnostic characters.

Themeda avenacea (F. Muell.) Dur. & Jacks., Index Kewensis Suppl. 1, 424 (1906) *Anthistiria avenacea* F. Muell., Fragm. Phyt. Aust. 5:206 (1866).

7 miles N.W. of Bylina Station, dominant in depressions in gilgaied heavy soil plain, *Lazarides* 3130, 26.vi.1952 (CANB, BRI, NT, NSW, MEL, AD, PERTH, K, US).

A new record for the Northern Province of Western Australia; widespread throughout Australia except Victoria and Tasmania.

Triodia fitzgeraldii N.T. Burbidge, J. Roy. Soc. W. Aust. 30:25 (1946).

Dillon's Springs, 46 miles S.E. of Wyndham Township, common on rocky skeletal slope of sandstone hill with *Triodia plectrachnoides*, *Lazarides* 3169, 10.viii.1952 (CANB, BRI, NT, NSW, MEL, AD, PERTH, K, US).

This collection from the type locality is only the second record for the species. The following notes are taken from a field description of the above collection:—"Tussocks 1 ft high and 18 in. wide. Flowering culms 2 ft high. Lamina dark-green, terete, strongly pungent, non-resinous."

Triodia inaequiloba N.T. Burbidge, Aust. J. Bot. 8:391 (1960).

Only the type collection known. At the type locality (Mt. Amherst Range), the species dominates a narrow zone on the upper granitic slopes immediately below the scarp. The species grows in large tussocks 1½-3 ft high and 3-4 ft in diam. with flowering culms 3-4 ft high and bright green, non-resinous, erect leaves.

Triodia intermedia Checl, K. svenska Vetensk.-Akad. Handl. 52 (10):4-5 (1916).

10 miles N. of Fitzroy Crossing Township, common on red soil on limestone, *Lazarides* 3102, 17.vi.1952 (CANB, BRI, NT, MEL, K, US); 10 miles S.W. of Calwynyardah Station, dominant on yellow podsolic soil, *Lazarides* 3107, 17.vi.1952 (CANB, BRI, NT, MEL, NSW, AD,

K, US); 44 miles S. of Denham River Station, dominant on skeletal soil on igneous rocks, *Lazarides* 3176, 13.viii.1952 (CANB, BRI, NT, K, US).

The species is more common in the strongly dissected Halls Creek area, where it dominates very large areas in association with *Eucalyptus brevifolia* open woodland, than in the Fitzroy River basin from which it was originally recorded; an endemic of the Kimberley District and adjacent areas of the Northern Territory. The prominently winged palea provides an easily recognizable characteristic.

Triodia racemigera C. A. Gardner, Fl. W. Aust. 1(1):77 (1952).

10 miles N.E. of Flora Valley Station, dominant on volcanic outcrops with *Eucalyptus terminalis*, *Lazarides* 3183, 20.viii.1952; "The Razorbacks" near 65 mile peg on Wyndham-Darwin road, Kimberley, crevice in rock face, *Burbidge* 5189, 17.iv.1956; near Kimberley Research Station, Ord River, exposed slope under sandstone cliff, *Burbidge* 5721, 12.iv.1958 (CANB).

The above collections represent the second record for the species; also occurs in the Northern Territory. Field notes taken from No. 3183 include the following:—"Tussocky perennial with flowering culms 2-3 ft high. Tussocks up to 6 in. high and 1 ft wide."

Triodia roscida N. T. Burbidge, Aust. J. Bot. 1(1):176 (1953).

7 miles N.E. of Flora Valley Station, occasional on stony alluvial creek bank, *Lazarides* 3184.

20.viii.1952 (CANB, BRI, NT, NSW, MEL, AD, PERTH, K, US).

Previously known from Western Australia and the Northern Territory, each from a single collection.

Triodia wiseana C.A. Gardner, J. Roy. Soc. W. Aust. 27:166 (1942) var. *brevifolia* N.T. Burbidge, J. Roy. Soc. W. Aust. 30:24 (1946).

21 miles N. of Fitzroy Crossing township, common on brown calcareous desert soil, *Lazarides* 3103, 17.vi.1952 (CANB).

New record for the Kimberley district; previously known only from the extreme south-west of the Northern Province.

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12.—The Occurrence of Macropodidae on Islands and its Climatic and Ecological Implications

By A. R. Main*

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The islands of the western and southern coasts of Western Australia which support macropod marsupials have been formed by eustatic rise of the sea in post Pleistocene times; 15 of these islands support macropod marsupials. The smallest island supporting a population of macropods is only 240 acres in area. Two species are not found together in an insular situation until this is larger than 6 square miles in area. The problem of why only one species exists on islands 6 square miles in area or smaller is discussed in terms of past climate, time of isolation and inter-species competition. It is concluded that climatic differences at the time of isolation rather than inter-species competition probably account for the faunal differences in the Recherche Archipelago. Garden and Rott-nest Islands are thought to be a clear cut case of competitive success of the tammar and quokka respectively. Outstanding problems which need further attention are mentioned.

Introduction

The more extensive geographical distribution of animal species during past times is commonly inferred from two sorts of evidence, fossil occurrences, and isolated populations occurring outside the principal present geographical range of the species.

In Western Australia fossil mammals have been studied by Glauert (1910, 1912, 1914, 1948) and Lundelius (1957). Obvious examples of the second type are island populations. There are 15 islands on the west and south coast inhabited by macropod marsupials (see Fig. 1). Such populations are of special interest for the following reasons:

- (i) The islands were connected to the mainland during periods of lowered sea level at times of glacial advance during the Pleistocene. When glaciers melted and seas rose the islands were cut off from the mainland by the eustatic rise of the sea. Thus the origin of these insular populations can be precisely stated.
- (ii) When the species found on the offshore island no longer occur on the adjacent mainland it can be inferred that the restriction of the main geographical range must have been later than the cutting off of the insular population.
- (iii) The coastal islands arise from different depths of sea and if formed by eustatic rise in sea level cannot all be of similar age.
- (iv) The coastal islands containing faunal relicts are of different size, geology, floristic or faunistic diversity. Thus the

islands are a kind of field trial which has run over a relatively long period of time so that persistence of species can be measured against ecological factors in the environment. On most islands only one species of macropod is found, which suggests that a faunistic analysis in terms of inter-species competition would be possible.

The sizes of islands, and species occurring thereon, are listed in Table I.

The data of Table 1 raise two sorts of general problem, viz: (a) the order of island-size which will sustain one, two or three species, and (b) whether inter-species competition has operated to produce the single species populations which are characteristic of the smaller islands.

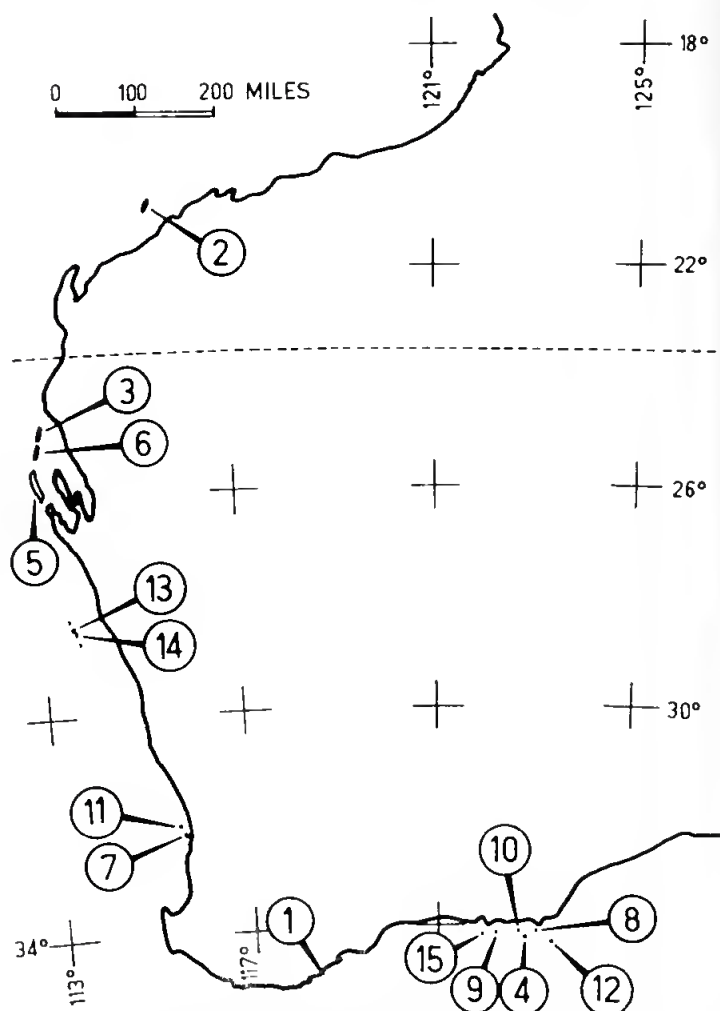


Fig. 1.—Locality map of islands referred to in text: 1 Bald; 2 Barrow; 3 Bernier; 4 Combe; 5 Dirk Hartog; 6 Dorre; 7 Garden; 8 Middle; 9 Mondrain; 10 North Twin Peaks; 11 Rott-nest; 12 Salisbury; 13 Wallabi East; 14 Wallabi West; 15 Wilson.

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Island Size and Diversity of Habitat

There are numerous islands in the region under discussion which do not support macropods and are therefore not included in Table 1. Of these the majority are mere rocks or rookeries of sea birds. However, a few support a depauperate littoral or limestone flora and one or two species of reptiles, but no mammals; while an occasional island supports a small mammal species, e.g. Christmas (Recherche Archipelago) on which is found an *Isodon* species. Not all of these islands can be regarded as small. Some e.g. North Island (Abrolhos) (940 acres) or Christmas Island (830 acres) are much larger than

Apart from island size, food and cover are important. Examination of Table 1 shows that neither the presence of trees nor great floral diversity is absolutely essential. Two of the Recherche islands (Boxer and Sandy Hook), 0.5 and 1.1 square miles in area respectively, have *Melaleuca* sp. and 87 and 100 + plant species respectively, but no macropods. Likewise the geology of the island, whether limestone or granite, does not appear to be of critical importance in determining which species of macropod is present except insofar as it provides the material for the tumbled piles of granite boulders utilised as cover by rock wallabies (*Petrogale*). During

TABLE I

Offshore islands, macropod present, size and ecological comment

| Island | Area square miles | Macropod | Floral diversity (No. of species) | Ecological | |
|------------------|-------------------|---|--------------------------------------|--|---|
| | | | | Trees | General |
| Combe | 0.4 | <i>Petrogale p. hacketti</i> | 23 | None | Granite boulders calcareous sand, saltbush flat |
| Wilson | 0.5 | <i>Petrogale p. hacketti</i> | 37 | <i>Melaleuca</i> 1 <i>Eucalyptus</i> | Granite dome |
| North Twin Peaks | 1.1 | <i>Protemnodon eugenii</i> | 90 | 3 <i>Eucalyptus</i> <i>Melaleuca</i> <i>Acacia</i> | Granite gneiss no limestone |
| Salisbury | 1.3 | <i>Petrogale p. hacketti</i> | 26 | None | Granite and limestone. Shrubs only |
| Wallabi, East | 1.4 | <i>Protemnodon eugenii</i> | 35 | 1 <i>Eucalyptus</i> | Coralline limestone and dunes |
| Wallabi, West | 2.3 | <i>Protemnodon eugenii</i> | 31 | No <i>Eucalyptus</i> | Coralline limestone lagoon deposit and dunes |
| Bald | 3.0 | <i>Setonix brachyurus</i> | 85 | <i>E. lehmannii</i> <i>Melaleuca</i> | Granite and coastal limestone |
| Mondrain | 3.6 | <i>Petrogale p. hacketti</i> | 135+ | 4 <i>Eucalyptus</i> | Lacks limestone contains sand plain flora |
| Middle | 4.2 | <i>Protemnodon eugenii</i> | 136+ | 4 <i>Eucalyptus</i> 2 <i>Melaleuca</i> | Granite, metasediments coastal limestone |
| Garden | 4.5 | <i>Protemnodon eugenii</i> | 79 | No <i>Eucalyptus</i> | Coastal limestone and recent sand dunes only |
| Rottnest | 6.0 | <i>Setonix brachyurus</i> | 110 | Formerly a Thart (<i>Eucalyptus gunnisonii</i>) association <i>Melaleuca</i> , <i>Acacia</i> | Coastal limestone shell beds and recent dunes |
| Dorre | 18 | <i>Lagostrophus fasciatus</i> <i>Lagorchestes hirsutus</i> <i>Bettongia lesueuri</i> | 98 | 3 <i>Eucalyptus</i> 2 <i>Acacia</i> <i>Heterodendron</i> | Sandstone and red sands some limestone |
| Bernier | 18 | <i>Lagostrophus fasciatus</i> <i>Lagorchestes hirsutus</i> <i>Bettongia lesueuri</i> | 91 | 2 <i>Eucalyptus</i> 2 <i>Acacia</i> <i>Heterodendron</i> | Sandstones and red sands some limestone |
| Barrow | 80 | <i>Macropus robustus isabellinus</i> <i>Lagorchestes euaspiculatus</i> <i>Petrogale lateralis</i> | Not known | | |
| Dirk Hartog | 240 | <i>Lagostrophus fasciatus</i> <i>Lagorchestes hirsutus</i> <i>Bettongia lesueuri</i> | 66 | 2 <i>Eucalyptus</i> 6 <i>Acacia</i> <i>Heterodendron</i> | Sandstones and red sand with some limestone |

* Islands of Recherche: data from Willis, J. H. (1953). —The Archipelago of the Recherche, 3a Land Flora. *Rep. Aust. Geogr. Soc.* No. 1: 1-35 and from R. D. Royce (personal communication).

Combe Island (Recherche) (240 acres). It is probable that some of these islands may have originally contained a population of macropods which has not persisted. Confirmation of this suggestion is possible in some cases when skeletal remains are found, as at North Island (Storr 1960). There is no evidence that this extinction occurred during historical times. On the other hand it is difficult to envisage that such islands as Figure of Eight (Recherche), with bare rocky slopes, could have supported macropods although the island is more than twice the area of Combe.

a recent visit to the island of the Recherche Archipelago Mr. R. D. Royce (personal communication) associated rock wallabies with those islands on which rectangularly jointed granite had produced a jumble of angular boulders which provided shelter in the form of "caves."

The eleven islands on which one species of macropod is found form a well-graded size series. Nevertheless Combe and Wilson are remarkably small compared with the larger islands of the series. The reality of the size break between Rottnest and Dorre needs confirmation on a more complete series of islands for it appears

that on islands between 6 and 18 square miles in area the environment becomes either extensive enough or sufficiently diverse for two or more species to co-exist. The examination of further islands intermediate in size between Rottneest and Dorre, perhaps within the Dampier Archipelago, would probably allow more accurate fixing of the smallest island which would contain two species. It would also be of interest to know whether the rock wallaby, tammar, and quokka are more similar in their ecological requirements and therefore more highly competitive than are the two hare-wallabies and the rat-kangaroo which co-exist on Bernier and Dorre.

Competition

The problems posed by the occurrence of single species on offshore islands has been long appreciated by local ecologists several of whom have attempted explanations. Clarke (1948, p. 141) accounted for the occurrence of the

Dr. R. W. Fairbridge had pointed out that the depths recorded on the Admiralty charts showed that Mondrain, Salisbury, Combe and Wilson were separated from the mainland prior to Middle and North Twin Peaks. Thus the outer islands near the edge of the continental shelf may have been isolated for a considerable period before the inner islands closer to the present mainland and, as V. N. Serventy notes, environmental factors may have favoured one habitat or the other and thus favoured the rock wallaby or tammar on the two occasions.

Since the foregoing was written much more is known of post Pleistocene climatic changes. Sea level changes can now be dated by means of radiocarbon dating (Godwin, Suggate and Willis 1958). The seas did not rise precipitately at the close of the glaciation (Godwin *et al.* op. cit.) and the periods when the first and last islands were isolated from the mainland are distantly separated in time (see Table II).

TABLE II

Islands of south coast and lower west coast of Western Australia, macropod present, and time of isolation

| Island | Rising from sea, fathoms | Macropod | Time of isolation years (B.P.) approx. |
|------------------------|--------------------------|--------------------|--|
| Salisbury | 45 | <i>Petrogale</i> | 15,000 |
| Combe | 33 | <i>Petrogale</i> | 12,500 |
| Wallabi, East and West | 29 | <i>Protemnodon</i> | 11,500 |
| Wilson | 27 | <i>Petrogale</i> | 11,000 |
| Mondrain | 25 | <i>Petrogale</i> | 10,500 |
| Middle | 18 | <i>Protemnodon</i> | 9,500 |
| Bald | 15 | <i>Setonix</i> | 9,000 |
| North Twin Peaks | 10 | <i>Protemnodon</i> | 8,000 |
| Rottneest | 5 | <i>Setonix</i> | 7,000 |
| Garden | 5 | <i>Protemnodon</i> | 7,000 |

quokka (*Setonix brachyurus* (Q. & G)) on Rottneest and the larger tammar (*Protemnodon eugenii* (Desmarest)) on Garden Island as follows:

Setonix, being physically inferior to *P. eugenii* would migrate to the end of the promontory (formed by the rising seas) (the present Rottneest) leaving *P. eugenii* in the Garden Island region. Subsequently the promontory was cut by the sea leaving the two species occupying different islands.

This interpretation obviates any consideration of inter-species competition but the concept of distribution being related to "physical inferiority" has no support as pointed out by D. L. Serventy (1951), who interpreted the present distribution of species on Garden Island and Rottneest as being the outcome of inter-species competition. V. N. Serventy (1953, p. 43-45) when discussing the mammal fauna of the Recherche Archipelago was presented with the problem of explaining the presence of different species (rock wallaby, *Petrogale penicillata hackettii* Thomas) and tammar on adjacent islands. He followed D. L. Serventy and accounted for the recorded distribution by postulating inter-species competition "based on Gauses' law" (p. 45). However, he adds that

From Table II it is apparent that *Petrogale* is restricted entirely to islands of the south coast older than 10,500 B.P. With the exception of the two Wallabi islands (11,500 B.P.) there is no overlap in age between those islands on which *Petrogale* occurs and those in which *Protemnodon* or *Setonix* are found. There are thus two problems (i) the apparent anomaly in the age and fauna of the Wallabi islands and (ii) the possible explanation for the almost complete separation of the islands of Table II into an older and a younger group with different faunas.

From present day distributions of the three species it is clear that *Petrogale* occupies the climatically drier environment (Table III). Thus the presence of *Petrogale* on islands older than 10,500 years suggests that such islands were isolated in a drier climatic period than the more recent islands. Mainland occurrences of *Petrogale* suggests that drier climate must be accompanied by rock outcrops and rock shelter to provide a suitable habitat. Such environmental prerequisites are not present on either East or West Wallabi islands in which case it is possible that *Protemnodon*, relieved of competition with *Petrogale* may have extended its range into a drier environment in which it was later isolated by rising seas. Such an hypothesis would

explain the apparent anomaly in the macropod fauna of the Abrolhos. However, it also clearly indicates that further work on the biota of these islands is necessary.

The broader implications of the data of Table II centre around the question of whether at the time of the more recent isolation, the climate was similar to that of the earlier isolation. If it was not, the events which led to the persistence of different species on the earlier and later isolated islands would not be similar and the end result (different species on each island) is not comparable in terms of a field experiment in competition.

The problem can be stated another way; it is desired to distinguish between the two following possibilities:

- (a) That two species occurred simultaneously in the same area (zone of overlap, see below).
- (b) That two species occurred chronologically in the same area. In their mainland distribution the three species (quokka, tammar, and rock wallaby) are essentially allopatric. In regions of overlap they are separated by marked habitat preferences. Under these conditions it is difficult to envisage that inter-species competition occurs. On islands, however, species do occupy habitats that differ remarkably from that preferred on the mainland, e.g. on Rottnest the quokka occupies shrub steppe while on the mainland it is restricted to swamp thickets. Data for all three species are summarised in Table III.

It is conceivable that two species could have been in the same general area (zone of overlap) and were cut off together on the same island. In this case we might expect to find islands of similar age with different species, e.g. Rottnest and Garden Islands. Should the presence of rock shelter prove to be the controlling factor for the rock wallaby then, from the fact that some islands are now inhabited only by rock wallabies, one cannot infer that the tammar did not occur in the vicinity during the past. Among the islands of the Recherche, however, there is, as already noted (Table II), complete separation of the island fauna into an older with *Petrogale* and a younger with *Protemnodon*. This argues against co-existence (zone of overlap) prior to island formation and suggests a climatic change between the isolation of the older and younger islands. Should the climate have become wetter than previously the tammar may have replaced the rock wallaby on the mainland and tammar would be included in the fauna of any islands subsequently formed in this area.

In Europe and North America the close of the Pleistocene was marked by a number of climatic oscillations and it would not be surprising if similar changes marked the end of the Pleistocene in Australia. The older and younger island faunas discussed above would represent one oscillation.

The sorts of changes in the atmospheric circulation which could produce such climatic changes can be discussed in terms of theoretical meteorological concepts (Willett 1953) and it is instructive to do so in the present case in order to see whether the theory predicts a change

TABLE III

Preferred environmental conditions as indicated by habitat occupied throughout the present mainland occurrence, contrasted with the environments present on the islands where animals are now abundant

| Species | Mainland | Island |
|---|---|--|
| <i>Setonix brachyurus</i> | Permanently wet swamps which do not dry in summer. Vegetation provides deep cool shade, grows throughout year and provides dense cover. | <i>Rottnest</i> —Dry steppe-like arid situation produced under grazing climax. Vegetation markedly seasonal in growth, provides little shade or cover. Water limited during summer. <i>Bald</i> —Similar to adjacent mainland; dense patches of vegetation growing continuously due to persistent rains. |
| <i>Protemnodon eugenii</i> ... | Not known to occur in wetter south-west, limited to thickets in the sclerophyllous woodland savannah woodland, and shrub woodlands. | <i>Garden</i> — <i>Acacia</i> thickets with <i>Callitris</i> and <i>Melaleuca</i> —no free water. <i>North Twin Peaks</i> — <i>Eucalyptus</i> , <i>Acacia pumiloba</i> , <i>Melaleuca</i> , <i>Callitris</i> —? no free water. <i>Middle</i> —Granite, metasediments, coastal limestone— <i>Eucalyptus</i> and <i>Melaleuca</i> . <i>Wallabi (East and West)</i> — <i>Eucalyptus</i> , <i>Acacia</i> , no permanent fresh water. |
| <i>Petrogale penicillata hacketti</i> ... | Rocky and precipitous hills of granite or meta-sediments with boulders or caves in the shelter of which the animal retreats during the day. In savannah woodland and sclerophyllous woodland and communities on the dry side of these. Does not appear to be dependent on free water. | <i>Wilson</i> — <i>Eucalyptus</i> , <i>Acacia</i> , <i>Melaleuca</i> and <i>Astoria</i> . Forming thickets on the north and east side of high granite area. South side predominantly wind planed shrubs, e.g., <i>Leacopogon</i> , <i>Beyeria</i> , <i>Pinnia</i> and <i>Calcephalus</i> and <i>Carpobrotus</i> . Mostly rocky with sparse patches of soil. <i>Mumbrain</i> —Granite, lacks limestone; has <i>Eucalyptus</i> , <i>Acacia</i> , <i>Melaleuca</i> , <i>Casuarina huegeliana</i> , patches of heathland— isolate of mainland habitat. <i>Combe</i> —Sandy over granite with granite boulders; is a saltbush (<i>Atriplex</i>) flat. <i>Salisbury</i> —Granite headland plus consolidated Pleistocene beach dunes (— acolianite). Shrubs or dense thickets up to 5 feet high. |

from a dry to wet about the time of isolation of the younger (tamar) islands in the Recherche.

Possible Climatic Change

Meteorologists have been struck by the similarity of the climate at the time of glacial advance and retreat to the index cycle (for description see Rossby and Willett 1948). Willett (1948) points out that an ice age is like a low index pattern while an interglacial is like a high index pattern.

Craig and Willett (1951, p. 383) further discuss the index cycle. They point out that the passage from a high to a low index is characterised by the splitting of cyclones and anticyclones with predominantly east-west orientation of the major axis into centres of action with north-south orientation. "The result is an increase of latitudinal exchange of air masses and storminess and of extreme air mass contrasts in lower middle latitudes." They conclude (p. 389). "These considerations suggest that glacial epochs, stages and sub-stages, periods of climatic stress such as the sub-atlantic period and stormy centuries result from the predominance over various periods of time of low index conditions . . ."

There is geological evidence from both Europe and North America that during the last 20,000 years glaciers retreated and advanced several times. These alterations in the ice sheet have been dated by means of radiocarbon dating and are summarised in tabular form by Emiliani (1955), Horberg (1955) and Wright (1957). From these data it seems that periods of retreat were reversed between 14,000-12,000 B.P. and again about 11,000 B.P. At about 10,750 Wright (from Gross 1954) cites the climate as being "very cold, maritime subarctic" (previous cold periods being continental). This climate corresponds with the Fennoscandian stage of Europe and the Mankato of North America. Presumably the climate of Europe was marked by an extreme development of the low index cycle. The glacial climates have always been parallel in both hemispheres, and it seems likely that this extreme low index cycle was world wide.

From Table II it is apparent that in the Recherche Archipelago, islands isolated prior to about 10,500 contain *Petrogale* while those isolated later have *Protemnodon*. *Protemnodon* prefers a wetter environment with assured winter-type rainfall of 90-150 wet days a year and it seems possible that it extended its range eastward into a region formerly occupied by *Petrogale* which was becoming wetter because of the greater storminess of a low index period. Thus change in the climate deduced from glacial happenings agrees with the change in species isolated on the more recently formed islands of the Recherche and the agreement is thought not to be coincidental.

Discussion and Conclusions

The data presented suggest that it is possible to establish the minimum area necessary for the natural containment of one species of small macropod. It also suggests the order of the island area necessary for containing two species.

A field investigation of diet in these minimal areas may perhaps reveal that some animals are leading a marginal existence. This aspect should be investigated.

The dating of sea level rises supports the suggestion of Fairbridge (in Serventy 1953), and shows that the occurrences of different species on adjacent islands of the Recherche Archipelago need not necessarily reflect the outcome of inter-species competition. The interpretation is based on the usual biogeographical assumption that animals (tamar and rock wallaby) which are now essentially allopatric will also have been separated in the past.

On Bald Island competition may have operated but we have insufficient data on which to say whether at the time of isolation only the quokka was present or whether both tamar and quokka occurred. Most probably both were present and competition eliminated the tamar.

On the west coast both tamar and quokka are present on the mainland and almost certainly were present together when Garden and Rottnest were isolated. The present distribution appears clearly interpretable in terms of inter-species competition as already interpreted by D. L. Serventy (1951). In the case of East and West Wallabi there are no data on which to assert that the quokka was present, as well as the tamar, when these islands were part of the mainland. Thus it is not possible to infer that competition was the cause of the present distribution.

Since the various islands apparently are not of comparable age the taxonomic concepts of the species and sub-species status of the various insular and mainland populations should be re-investigated, in particular, as noted by Tate (1948), the disposition of the Garden Island and Wallabi Island tamars in the same sub-species and different from the mainland one. See also Glauert (1934) and Troughton (1941), each of whom has a different arrangement.

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crayfish in Western Australia. Dr. George and Messrs. Royce and Brown made their field notes available to the author. Data on the ocean depths in the Recherche Archipelago were supplied by Messrs. Poole Brothers. The Golden Gleam Canning Co. of Geraldton and Mr. A. J. Fraser, Director State Fisheries Department, provided transport to the Abrolhos on separate occasions.

Professor H. Waring and Messrs. J. H. Calaby and R. D. Royce read and criticised the manuscript.

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13.—The Geology of the North-Eastern Margin of the Fitzroy Basin between Hawkstone Creek and Oscar Range, Western Australia

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The area described in this paper includes part of the north-eastern margin of the Fitzroy Basin and stretches from long. $124^{\circ} 30' E.$ to $125^{\circ} 10' E.$ The sedimentary strata in the area consist of: Pleistocene to Recent deposits; Permian Grant Formation; Lower Carboniferous Laurel Beds; Upper Devonian Fairfield Beds, Napier Formation, Van Emmerick Conglomerate and Behn Conglomerate; and Middle Devonian Pillara Formation. The middle part of the western portion is occupied by a syncline whose axis trends north-west. The south-western corner of the area is occupied by the north-eastern slopes of a buried ridge which is the north-western continuation of the Oscar Range. The area exhibits strong faulting and fracturing, the main faults trending approximately parallel to the Napier Range.

Introduction

The area described below includes part of the north-eastern margin of the Fitzroy Basin and stretches from long. $124^{\circ} 30' E.$ to $125^{\circ} 10' E.$ The emphasis in this paper is on elucidation of stratigraphy and structure, with special reference to the Upper Devonian Fairfield Beds and the Lower Carboniferous Laurel Beds.

Stratigraphy

The sedimentary strata consist of: Pleistocene to Recent deposits; Permian Grant Formation; Lower Carboniferous Laurel Beds; Upper Devonian Fairfield Beds, Napier Formation, Van Emmerick Conglomerate and Behn Conglomerate; and Middle Devonian Pillara Formation.

The average thicknesses of the strata are as follows:

- Pleistocene to Recent—0-100 feet.
- Permian Grant Formation—700 feet.
- Lower Carboniferous Laurel Beds—1,300 feet.
- Upper Devonian Fairfield Beds—1,500 feet.
- Napier Formation—1,500 feet.

Pleistocene to Recent

Pleistocene to Recent deposits are alluvium, sand, gravel, and travertine. The largest rivers, such as the Lennard and Barker Rivers, have scored deep valleys in the marls, shales, siltstones and calcarenites of the Upper Devonian Fairfield Beds and the Lower Carboniferous Laurel Beds, and these valleys are now filled with alluvium, mostly sand, gravel, and some silt. Sand and gravel are also usual on the areas underlain by the Permian Grant Formation, and represent its disintegration products. Much silt, fine sand, and clayey silt and sand are deposited on the plains underlain by Upper Devonian Fairfield Beds and Lower Carboniferous Laurel Beds.

Box 28a, 601 St. Kilda Road, Melbourne, Victoria.

Permian

Grant Formation.—The Grant Formation consists of brown to white, fine- to medium-grained sandstone, which is often cross-bedded. The sandstone contains lenses of rounded to sub-rounded pebbles as well as scattered pebbles and gritty layers. The average thickness of the pebble lenses is 1 foot, and the pebbles in them, which are mostly quartzite, range in size from $\frac{1}{4}$ inch to 4 inches. Very often the sandstones of the Grant Formation contain clay pellets.

Some sandstones of this formation are flaggy, with the flags from 1 to 5 inches thick. Some flaggy brown ferruginous shaley sandstone is also encountered in the exposures of Grant Formation at the south-western corner of the area mapped. The thickness of the flags in this shaley sandstone is from $\frac{1}{4}$ to $1\frac{1}{2}$ inches.

In the west of the area the Grant Formation varies in thickness from approximately 700 to 1,500 feet.

The author thinks that the deposition of sandstones on the Lennard Shelf to which a Grant Formation age is assigned, may have commenced in Carboniferous times and continued into the Permian. These Lennard Shelf sandstones represent marginal deposits of the Fitzroy Basin. The unit underlying the Grant Formation in Grant Range No. 1 and Fraser River No. 1 bores, has been named the Anderson Formation and assigned an Upper Carboniferous age (McWhae, Playford, Lindner, Glenister and Balme 1958, p. 50). The author considers that the lower portion of the deposits of the Grant Formation exposed in the area mapped probably corresponds to the Upper Carboniferous Anderson Formation which is encountered in the deeper parts of the Fitzroy Basin. The latter formation consists mostly of reddish brown shales and white sandstones. Reddish brown shales crop out along the Station Creek Fault at Station Creek, where they are upturned vertically by drag along the surface expression of the fault. If the lower part of the Grant Formation on the Lennard Shelf does belong to the Upper Carboniferous, then the deposition of these sediments in the Fitzroy Basin can be correlated better with the corresponding deposition in the Bonaparte Gulf Basin.

Lower Carboniferous

Laurel Beds.—The Lower Carboniferous Laurel Beds are exposed in the area mapped as shown by fossils and lithology. Species of *Productus* were found at Mt. Percy in the eastern part of the area and are identical with species found south-west of the Oscar Range at Laurel Downs.

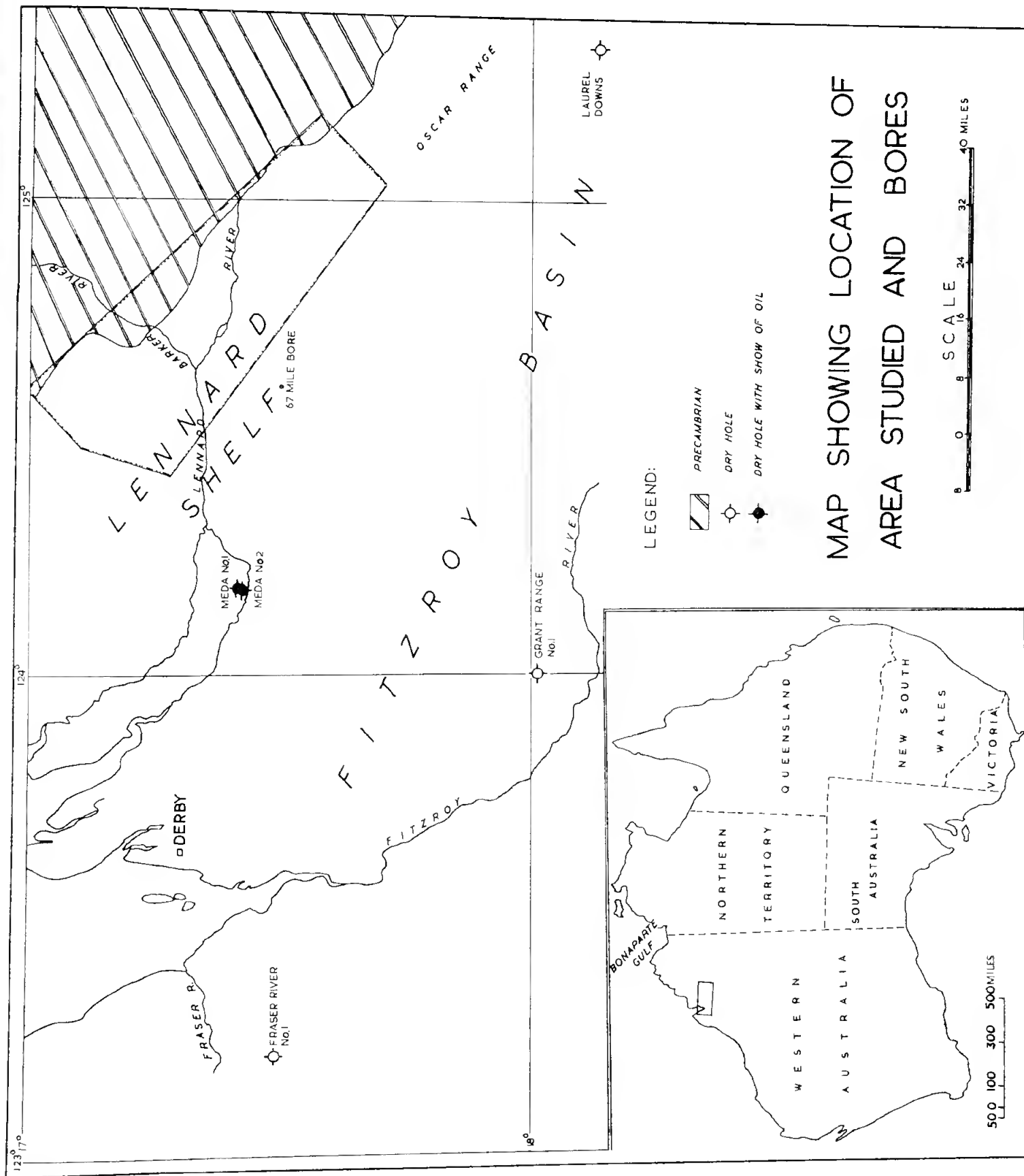


Fig. 1.

the type area of the Laurel Beds in the Fitzroy Basin. The boundary of the Laurel Beds can be distinguished fairly exactly in the mapped area. A characteristic marker bed with *Cyrtospirifer* occurs in the upper part of the Upper Devonian Fairfield Beds at Station Creek, north of Mt. Percy, and at the Lennard River $6\frac{1}{2}$ miles west of Windjana Gorge. The first appearance of the overlying Laurel Beds can be estimated relative to this marker bed. For this reason, the Laurel Beds have also been identified at the lower part of Mt. North Creek.

Slump-folding is characteristic of the Laurel Beds and is widely encountered at Station Creek and to the north of Mt. Percy. It will be described below in the section on folding.

The calcarenitic facies of the Laurel Beds exposed north-north-west of Mt. Percy, close to the contact with the Grant Formation, resembles the upper layers of the Septimus Limestone on Mt. Septimus, in the Bonaparte Gulf Basin. The occurrence of many small crinoid stems in both localities is also striking, as is the appearance of *Camarotoechia* horizons. *Camarotoechia pleurodon* var. *tripla* Prendergast has accumulated in layers in the Laurel Beds at Station Creek, in the western part of the area mapped.

Guppy, Lindner, Rattigan and Casey (1958, p. 41) have recorded that a stratigraphic bore drilled near Laurel Downs penetrated 1,400 feet of marine, fossiliferous Laurel Beds. In the south-western corner of the area mapped the Laurel Beds are estimated to be approximately 1,300 feet thick.

Upper Devonian

Fairfield Beds.—The Upper Devonian Fairfield Beds consist of shales, marls, claystone, some siltstone and calcarenite. The bulk of the Fairfield Beds is made up of shales with thin calcarenite and a few siltstone intercalations. In the upper part, the intercalations are from 2 to 12 feet thick, though a calcarenite intercalation 16 feet thick is occasionally met, as in the Station Creek area.

Much larger thicknesses of calcarenite occur in the lower portion of the Fairfield Beds in the eastern part of the area investigated. There is a typical exposure of Fairfield Beds one mile north-east of Fairfield homestead. Two outcrops were encountered in this locality, at the foot of Napier Range where calcarenites of the Napier Formation are exposed and they represent the basal layers of the Fairfield Beds. These outcrops more or less resemble in lithology the outcrops of the upper part of the Napier Formation exposed on the western margin of Napier Range, 4 miles north-north-east of Old Napier Ruins. In the latter, the strata represent the transitional stage from Napier Formation to Fairfield Beds.

Upper Devonian Fairfield Beds exposed north-east of Mt. Percy consist mainly of shales with intercalated calcarenites. The shales, as usual for this type of sediment, form very poor exposures and it is likely that the areas between calcarenite exposures are commonly occupied by shales. The thickness of calcarenitic intercalations ranges from 6 to 10 feet. Thin layers of siltstone are occasionally present between the shales and marls. The Fairfield Beds exposed

in the southern channel of the Lennard River $6\frac{1}{2}$ miles west of Windjana Gorge consist mostly of shales, containing intercalations of clayey siltstone, clayey calcareous sandstone and sandy calcarenite. These intercalations are thin in comparison with the shale layers which vary from 60 to 120 feet in thickness. The shale itself often contains layers of brownish grey siltstone 0.5-1 inch thick.

To the east of the Barker River, $4\frac{1}{2}$ miles south-east of Napier Downs, greenish grey shales, grey calcarenites and sandy calcarenites of the Fairfield Beds are very poorly exposed. Shales predominate and the calcarenitic intercalations are thin, from 1 to 4 feet. The calcarenites are often flaggy, the average thickness of the flags being 1-3 inches.

The Fairfield Beds crop out weakly $\frac{1}{2}$ mile and $2\frac{1}{2}$ miles north-west of Old Napier Ruins where they consist of greenish grey shales and silty shales, with thin layers of yellowish grey calcarenite.

It is clear that Fairfield Beds are mostly shaley in the area north-west of Old Napier Ruins where a shale layer more than 400 feet thick was encountered. Shales and marls of considerable thickness contain grey sandy calcarenite layers which are very thin by comparison and vary from 1 foot 6 inches to 16 feet in thickness. However, some of these calcarenites are very fossiliferous, containing large populations of *Camarotoechia* and *Cyrtospirifer*.

A characteristic fossiliferous calcarenite horizon is located on Station Creek, $2\frac{1}{2}$ miles west of Old Napier Ruins. Underlain by shaley marl, it contains great numbers of *Cyrtospirifer*, and can be used as a marker bed as described above.

The total thickness of the Fairfield Beds in this area is estimated at approximately 1,500 feet.

Napier Formation.—The Upper Devonian is represented by the Fairfield Beds and the Napier Formation in the western part of the area under consideration. The Fairfield Beds, shown above, are mostly of shale, and calcarenitic intercalations there are subordinate. By contrast, the Napier Formation is mostly calcarenite with bioherms. Some sandy limestone also occurs. The upper part of the Napier Formation is composed of reef limestones and dolomites which are exposed in Windjana Gorge and 6 miles north-north-west of Old Napier Ruins. Small reefs are also encountered in the exposures of Napier Formation elsewhere in the western part of the mapped area. Bioherms of the Napier Formation in Napier Range, $3\frac{1}{2}$ miles north-north-east of Old Napier Ruins average 400 feet by 200 feet in size. Off-reef dips average about 25° . The small reefs are more or less interconnected and so form a string of reefs along the strike of the strata. This characteristic feature may be important when considering the reefs as possible reservoir rocks for oil accumulation.

In Wombarella Gap, approximately 682 feet of Napier Formation strata are exposed, and in Barker Gorge, approximately 1,142 feet. Red calcareous sandstone constitutes the lower part of the exposure whereas the upper part consists

1



2



PLATE I

1. The eastern side of the Barker Gorge east of the Barker Fault, showing the Upper Devonian Napier Formation predominantly layered clastics with small bioherm growths on the upper right of the picture.
2. Upper Devonian Napier Formation layered calcarenites in the Wagon Pass, Napier Range.

mostly of grey massive and bedded calcarenites and sandy calcarenites with bioherms. This portion of the sequence is fossiliferous and contains crinoids and spiriferids. In the section of the Napier Range 4 miles west-north-west of Napier Downs Station the Napier Formation is 2,263 feet thick and 8 miles north-west of the same station it is 2,281 feet thick. The average thickness of Napier Formation in the western part of the area is more than 1,500 feet.

The thickness of Napier Formation measured in Wombarella Gap does not differ much from that of 700 feet at Carpenter Gap 20 miles to the south-east. (Guppy *et al.* 1958, p. 39).

The Napier Formation in the eastern part of the Napier Range is considerably thinner than in the western portion of the area. Over the whole area, then, the Napier Formation varies in thickness from 682 feet to 1,500 feet and more.

Van Emmerick Conglomerate and Behn Conglomerate.—The Van Emmerick Conglomerate and Behn Conglomerate are lateral facies variations of the Napier Formation. They interfinger with, as well as replace, the shallow water marine facies. The Van Emmerick Conglomerate is exposed in Van Emmerick Range in the west of the area and consists of brownish grey conglomerate containing some lenses of fine-to medium-grained brown flaggy sandstone. These lenses average from 11 inches to 13 inches in thickness. The conglomerate is formed of well rounded boulders, cobbles, and pebbles of quartzite and granite, with some boulders also of schist and quartz. Quartzite boulders range from 1 foot to 1 foot 9 inches in diameter, and granite boulders from 6 inches to 3 feet.

The Behn Conglomerate crops out at Mt. Behn in the eastern part of the area and is lithologically similar to the Van Emmerick Conglomerate.

Guppy *et al.* (1958 p. 40) suggest that approximately 1,000 feet of these sediments have been preserved. The conglomerates represent torrential fanglomerates which interfinger seawards with the sediments of the Napier Formation.

Middle Devonian

Pillara Formation.—Only remnants are left of the Middle to early Upper Devonian Pillara Formation in the western part of the area mapped. Middle Devonian sediments crop out in the Napier Range in the eastern portion of Wagon Pass, at Windjana Gorge, north-west of Windjana Gorge, and north-east of Fairfield homestead.

An outcropping section of Pillara Formation 742 feet thick has been measured in the Napier Range 8 miles north-west of Napier Downs Station. The formation there is sandy and is composed of brown calcareous sandstone with intercalations from 14 to 36 feet thick of grey and pinkish sandy calcarenite. Thicknesses of 5 to 132 feet of brownish calcareous sandstone were measured in this section. Guppy *et al.* (1958, p. 22) have distinguished a basal arkosic sandstone facies which is well expressed also in the Napier Range. This quartzose clastic material is found in the northern part of Windjana Gorge and it forms the lower portion of the section measured 8 miles north-west of

Napier Downs homestead. McWhae *et al.* (1958, p. 37) write that "the basal calcarenites and quartz greywackes have their maximum development, which is in excess of 250 feet, along the Napier Range."

Lower Proterozoic and Archaeozoic

The Lower Proterozoic and Archaeozoic Lambco Complex of schist, gneiss, slate, phyllite, granite and granitized sediments, forms the basement and is exposed to the north-east of the Napier Range.

Structural Geology

Folding

The middle of the western portion of the area is occupied by a syncline whose axis trends north-west. This axis is clearly expressed to the north-west of Barker River, where north-westerly dips were encountered along Station Creek in the calcarenites belonging to the Laurel Beds, and in the sandstone outcrop of the Grant Formation 13 miles north-east of the south-western corner of the area mapped.

The south-western corner is occupied by the north-eastern slopes of the buried ridge which is the north-western continuation of the Oscar Range. Indicating this are the north-easterly dips observed in the Grant Formation sandstones of the Hawkstone Peak area. These dips are between 7° and 8°. South-westerly dips occur in the middle and eastern portions of the area. An exceptionally steep dip, caused by the north-north-easterly trending Wombarella Fault, was observed in the Fairfield Beds 4½ miles south-south-east of Napier Downs homestead.

The Laurel Beds are folded on a small scale, for example north-east of Mt. Percy, and at Station Creek. This folding can be accounted for by the nature of the strata involved, shales with thin intercalations of calcarenite, which are highly incompetent and can be easily subjected to slumping, crumpling and folding. Guppy *et al.* (1958, p. 41) state that "The beds show complex folding and faulting within the strata; this is in contrast to the underlying Upper Devonian, which dips south-west into the basin at 15°. The local complex folding is probably due to slumping." The above-mentioned structural feature is a very characteristic one for the Laurel Beds and it is always encountered where these beds are exposed.

Faulting

Pronounced faulting is expressed in the area under consideration. The main sets of faults more or less parallel the Napier Range. They occur in the Napier Range itself as well as to the south-west of it, and trend N.47°W. and N.60°W. Other sets of faults in the Napier Range trend N.35°W. and sets of faults and large fractures trending east-west; north-south; N.7°E.; N.20°E. and N.38°E. also occur there. The small Wombarella Fault, 4 miles south-east of Napier Downs, cuts the Napier Range at Wombarella Gap and continues on towards the south-west where it is expressed in Fairfield Beds. Very small horizontal as well as vertical displacements have taken place along this fault which has moved west block north-east and down, east block south-west and up.

Other faults with north-easterly trend cut the area and together with the Wombarella Fault, form a group with trend N.20°E. to N.30°E. The Barker Fault with a trend of N.25°E. belongs to this type. It cuts the Napier Range across the Barker River Gorge and there are prominent fractures associated with it in Napier Formation calcarenites and calcareous sandstones. Horizontal movements totalling one mile have occurred along this fault, and the movement is evidenced by tension fracturing in the gorge. Vertical movements have also taken place. The relative directions are: west block south-west and down, and east block north-east and up.

The Barker Fault continues from the Napier Range toward the south-west, passing to the west of the 67-Mile Bore, 19 miles south-west of Napier Downs. The bore is located on the upthrown side of the fault, and this explains in part why only approximately 2,500 feet of sedimentary strata were penetrated. The 67-Mile Bore is also on the north-western continuation of the Oscar Range buried ridge, which to the west of the bore is cut by the south-western continuation of the Barker Fault. It is evident that conditions favour a shallow basement in the vicinity of the bore.

Another fault belonging to the same set of north-easterly trending faults, and having a trend of N.30°E., was found at Mt. Percy. Evidence of this fault is displayed in the Grant Formation north-east of Mt. Percy. The fault crosses the Station Creek Fault, and leucite-rich intrusives at Mt. Percy have used this junction as a point of weakness. It should be mentioned here that the Station Creek Fault is breaking at this cross-point and changes direction beyond.

To the N.47°W. set belongs the fault in the Fairfield Beds, at Station Creek 2 miles west-north-west of Old Napier Ruins, which is herein named the Old Napier Fault. The south-eastern continuation of the Old Napier Fault has been found transecting the Fairfield Beds 5 miles south-south-east of Napier Downs. The Old Napier Fault is displaced by the Barker Fault. Its further continuation towards the south-east cannot be followed because of the thick alluvial cover.

The largest of the faults belonging to this north-westerly trending set is the Station Creek Fault, expressed at Station Creek 6 miles west-south-west of Old Napier Ruins. This fault continues on towards the south-east, where leucite-rich intrusives have used it as a line of weakness. The point where the Barker River joins the

Lennard River is on the line of the Station Creek Fault. It is a well known and interesting fact that topographic features such as this coincide with faulting. Dragging of strata along the Station Creek Fault occurs at Station Creek, 6 miles west-south-west of Old Napier Ruins, and at Mt. Percy. At Station Creek Laurel Beds and Grant Formation are involved. Hard, grey calcarenites of the Laurel Beds are dragged along the north-side of the fault and show that the north-east block has moved to the north-west. Fine-grained, brown, flaggy, shaley sandstones belonging to the Permian Grant Formation or to up-dragged, underlying, Upper Carboniferous Anderson Formation, are turned into a vertical position. Grant Formation sandstones are dragged along the fault at Mt. Percy, where the movement of strata indicates a south-easterly horizontal component of the south-west block. Here at Mt. Percy, the Station Creek Fault changes its trend, continuing further to the south-east with trend N.60°W. in the north-western end of the Oscar Range where it dips 79° N.E. The south-western block continues to be down-thrown as it is between Station Creek and Mt. Percy.

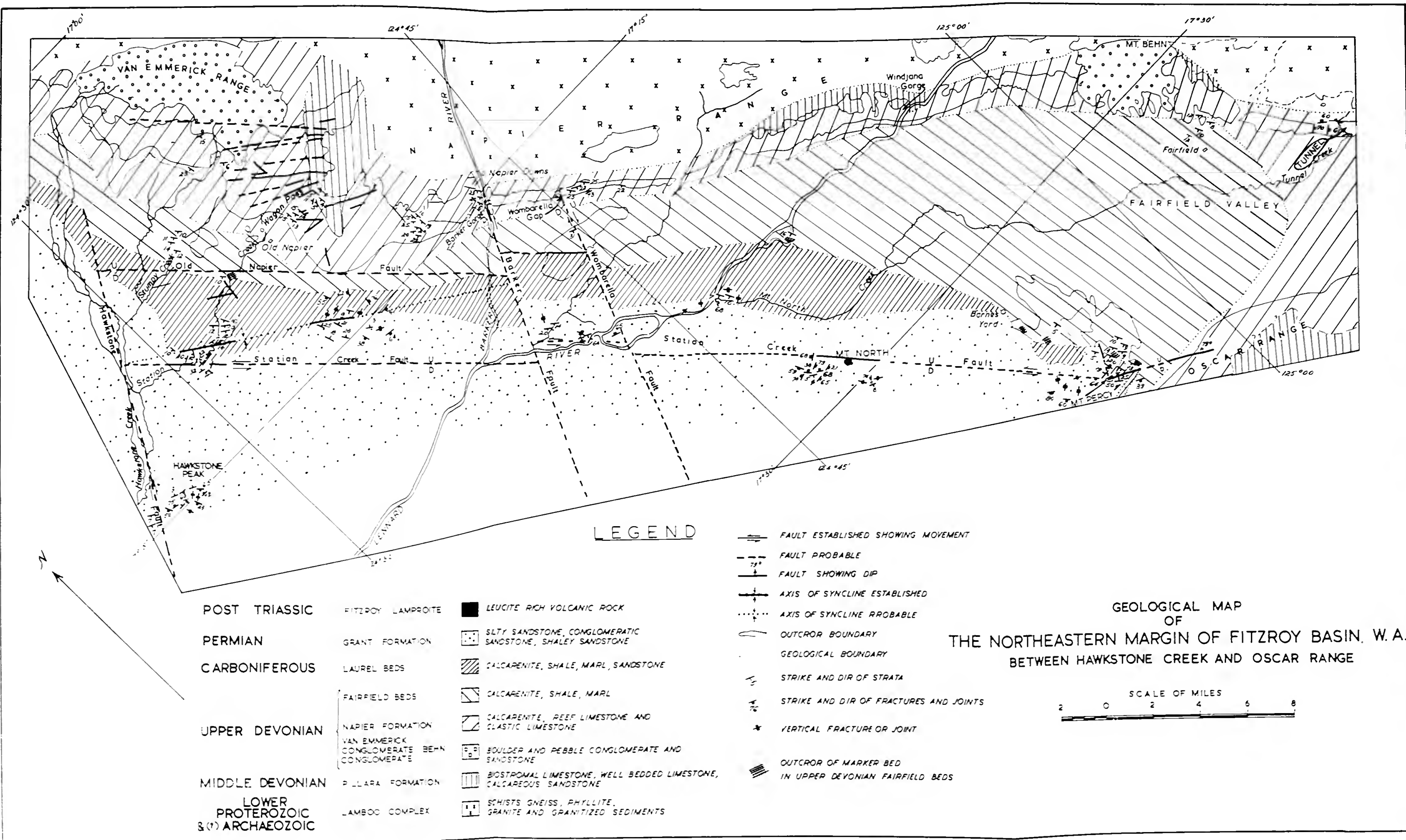
Several large tension fractures trending N.55°E. were encountered on the north-western end of Oscar Range. The author has found that this area is cut by several faults, all trending more or less parallel with the Oscar Range. As a result of this faulting a small graben is developed on the crest of the range. In the author's opinion, this is due to crustal sagging after the leucitic intrusives found release at the weak point where faults intersect at Mt. Percy.

Fracturing

Pronounced fracturing is connected with the strong faulting in the mapped area. The most favourable rocks, which were brittle and subjected to intensive fracturing, were the Grant Formation sandstones and the Napier Formation calcarenites. Tension fractures accompany the faults. A large tension fracture forms the "tunnel" in the Napier Formation calcarenites 5½ miles south-east of Fairfield homestead. This tension fracture trends N.50°E., dips 60° S.E., and is associated with faulting in the Napier Range trending approximately parallel with the range.

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Part 4

14.—An Annotated Catalogue of a Collection of Bird-Skins from West Pilbara, Western Australia

By G. F. Mees*

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When identifying and registering a collection of 76 species of birds from West Pilbara, in the North-West Division of Western Australia, the author found that no proper application of trinomials was possible without some revisional work. The results of this are presented here. In addition it seemed advisable to give particulars and measurements of every specimen contained in the collection, as so many subspecies have been described on the basis of size differences, without the actual measurements ever having been published.

As the main objective was identification of the material at hand, no thorough revisions have been made of the majority of species. In some cases however, more extensive notes are given, for example of *Cacatua tenuirostris*, *Ninox novaeseelandiae*, *Aegotheles cristatus*, *Coracina novaehollandiae*, *Amytornis striatus*, and *Meliphaga virescens*. Under *Pomatostomus temporalis* corrections of a number of type localities that had been restricted by Mathews are made. A new subspecies of *Ninox novaeseelandiae* from Western Australia is proposed, and it proved desirable to provide a new name for the subspecies of *Falco moluccensis* occurring on Celebes.

In July and early August, 1958, a party from the Western Australian Museum spent about three weeks collecting zoological material in West Pilbara (region of the Fortescue River and Hamersley Ranges), in the tropical north-west of Western Australia. Birds were collected mainly by Mr. K. G. Buller and the author, though several other members of the party made contributions. The collection consists of 76 species and 269 specimens. During the first half of our stay our base was Millstream Homestead, where we enjoyed the hospitality of Mr. and Mrs. S. Gordon; the second half we stayed, by kind permission of Mr. R. Parsons and Sir Edward Lefroy of Coolawanyah, in the abandoned homestead of Tambrey Station. The localities of collecting are indicated on the map (Fig. 1).

Ornithologically the region is well known, a fact largely due to the activities of the veteran collector F. Lawson Whitlock, who spent over 3½ months (July–November 1922) at Millstream on behalf of H. L. White. Though Whitlock (1923, p. 259) modestly stated that: "Of course, in a period of a few months it would not be possible to do more than run over such an extensive area

of country, and with small chances of observing rare or secretive forms of bird-life", it says much for the thoroughness of his investigations that, during an admittedly much shorter visit, we were not able to add a single species to the local list. The only addition to the avifauna of the region made here is *Neophema elegans*, of which Mr. E. W. Parsons forwarded a specimen collected at Hooley Station; this species had never been recorded from so far north and was probably a straggler.

Nevertheless, no apology is needed for presenting this paper. The justification for a full systematic discussion of the whole collection is to be found in the publications of Gregory M. Mathews. Though the species of Australian birds are very well known, Australian ornithology, especially where zoogeography and serious study of geographic variation are concerned, will for many years to come be handicapped by the chaos created at the subspecific level by Mathews. In recent years several ornithologists, notably Amadon, Condon, Keast, Mack and Mayr, have commenced the unrewarding task of cleaning up the nomenclatorial mess, created by a man who realized full well what he was doing as is evident from his statement: "... I have concluded that the value of subspecies is almost negligible in Australian Ornithology. In the Palaearctic Region they may be useful, but even here I think they have been much overrated; while if large series are examined from Australia very many subspecific forms can be differentiated, but larger series always link most extreme cases up very quickly" (Mathews 1917a). Since practically all named Australian subspecies were created by Mathews himself it is surprising that this condemning statement did not deter him from continuing the production of subspecific names (useless by his own admission) at an undiminished rate. Fortunately I need not give an appreciation or depreciation of the ornithologist Mathews, for this was done in an admirable way by Serventy (1950).

For the loan of material and for information concerning specimens under their care I am indebted to Dr. D. Amadon (American Museum of Natural History, New York), Mr. H. T. Con-

*Western Australian Museum, Perth, Western Australia.

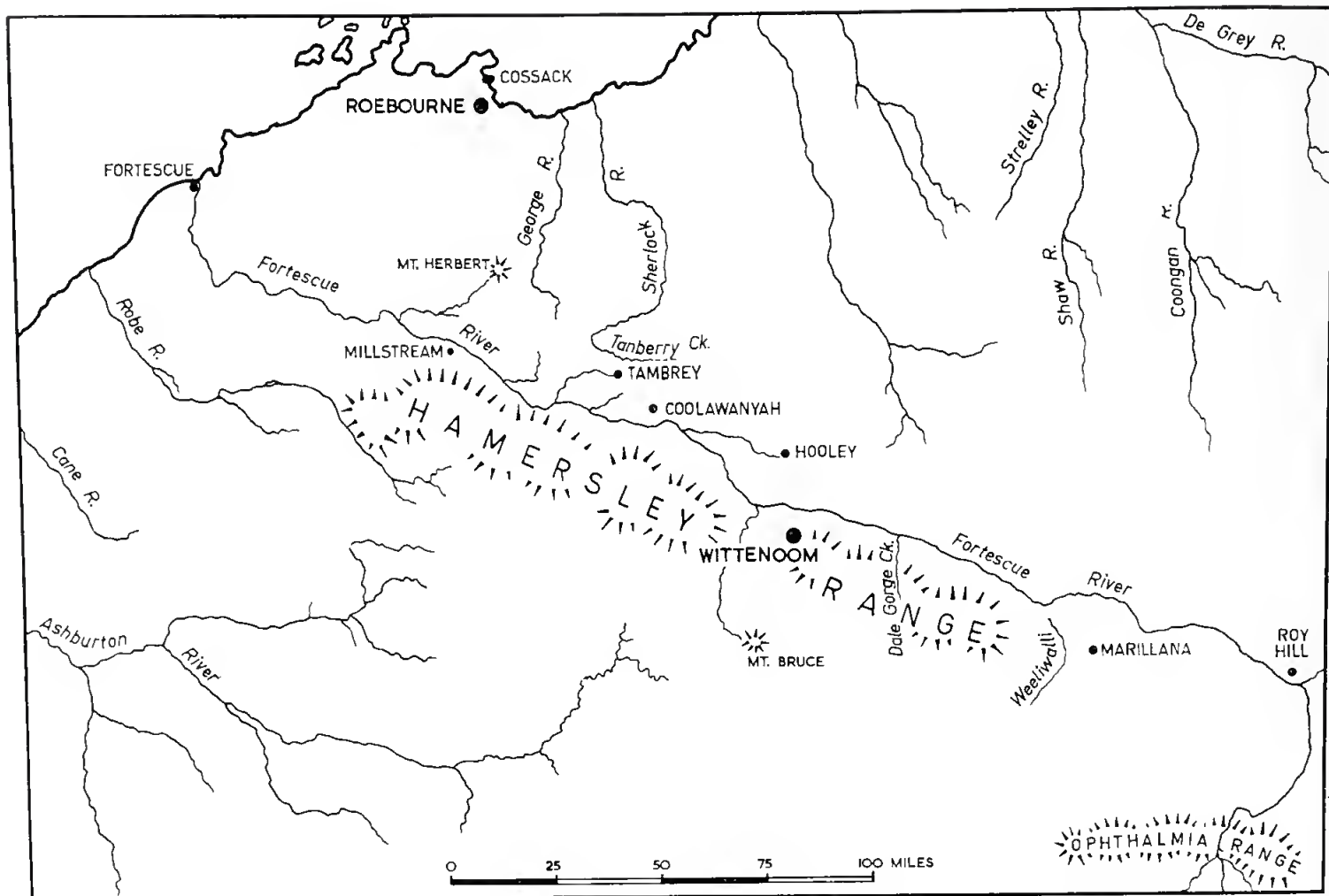


Fig. 1.—Map of the Fortescue River and Hamersley Ranges, showing collecting localities.

don (South Australian Museum, Adelaide), Dr. Chr. Jouanin (Muséum National d'Histoire Naturelle, Paris), Dr. G. C. A. Junge (Rijksmuseum van Natuurlijke Historie, Leiden), Dr. J. A. Keast (Australian Museum, Sydney), Mr. G. Mack (Queensland Museum, Brisbane), Mr. A. R. McEvey (National Museum of Victoria, Melbourne), Mr. R. Wagstaffe (Liverpool Public Museums). Dr. L. B. Holthuis (Leiden) supplied me with information concerning names based on hybrids.

***Dromaius novae-hollandiae* subsp.**

Emu

Five chickens taken on Millstream Station were presented to us by Mr. Stuart Gordon (A 8324-28). Though specimens were repeatedly observed, the species did not give an impression of being very common in the region.

Podiceps novae-hollandiae novae-hollandiae

Stephens

Dabchick

Podiceps Novae Hollandiae Stephens, in Shaw's Gen. Zool. XIII, pt. I, 1825, (1826?), p. 18—New Holland.

One specimen (Table I)

A few pairs were present on the larger lakes particularly in the Fortescue River. A revision was given by Mayr (1943).

***Phalacrocorax sulcirostris sulcirostris* (Brandt)**

Little Black Cormorant

Carbo sulcirostris Brandt. Bull. Sci. Acad. Imp. Sci. St. Petersb. 3, 1837, p. 56—*Terrae australes*—New South Wales (reference copied).

Mesocarbo ater territorii Mathews, Birds. Aust. IV, 1915, p. 176—Hermit Hill, Northern Territory.

One specimen (Table II)

Discussion. Mathews (1912c, 1914-1915) has discussed the applicability of the name *ater*, but as Berlioz (1927) has shown, he was wrong as the type of *ater* proved to belong to *P. magellanicus* Gmelin.

The name *territorii* is nowadays generally accepted (Peters 1931, Hoogerwerf 1947, 1954, and other publications by the same author, Smythies 1957). The description of this race is one of those gems so richly found in Mathews's works: having given a plate and a full description under the name *Mesocarbo ater ater*, he adds as a kind of afterthought: "The bird figured and described is a male, collected at Hermit Hill, Northern Territory, on the 7th August, 1894, and is the type of *Mesocarbo ater territorii*". Nowhere appears the slightest suggestion that Mathews considers the bird in any way distinct from the nominate race and I wonder if perhaps §114 sub (3) of the International Code of Zoological Nomenclature may be applicable, for there is no indication that the name *territorii*, as published, was intended for use in zoological nomenclature.

As far as I know nobody has ever supplied evidence that *territori* differs from *sulcirostris* at all. Not having examined material from eastern Australia, I am unable to settle the issue finally, but until evidence to the contrary may be brought forward I prefer to regard *territori* as a synonym.

Anhinga rufa novae-hollandiae (Gould)

Darter

Plotus Novae-Hollandiae Gould, Proc. Zool. Soc. Lond. 15, 1847, p. 34—The rivers of the whole of the southern coast of Australia.

Plotus novae-hollandiae derbyi Mathews, Aust. Avian Rec. 1, 1912, p. 74—Derby, North-west Australia.

One specimen (Table III).

Discussion. *P. n. derbyi* was described as differing from *novae-hollandiae* "in its larger wing-measurement, viz. 364 mm". As was his habit, no comparative measurements were given by Mathews.

Adult specimens in the Western Australian Museum have the following wing-measurements:

S. W. A. M: 348; ♀: 337, 342, 348, 348; sex?: 339, 343.

Derby, N. W. A. ♀: 319.

South Alligator R., N.T. ♂: 331.

If anything, these figures suggest that the northern birds are smaller, not larger. Peters (1931) had synonymised *derbyi* with *novae-hollandiae*.

Notophoxyx pacifica (Latham)

Pacific Heron

Ardea pacifica Latham, Index Orn., Suppl., 1801, p. lxxv—New South Wales (reference copied).

One specimen (Table IV)

Discussion. Mathews (1913-1914) withdrew his race *alexandrae* that was supposed to be darker on the back, though later (Mathews 1931) he upheld it again. This species cannot be divided in geographical races.

Nycticorax caledonicus hilli Mathews

Nankeen Night-Heron

Nycticorax caledonicus hilli Mathews, Novit. Zool. 18, 1912, p. 233—North-West Australia (Parry's Creek).

One specimen (Table V)

Discussion. According to Mathews (1912a) the birds from northern Australia would differ from those inhabiting southern Australia in their paler coloration. Mathews (1913-1914) himself concluded that only one race inhabits Australia, which is confirmed by Peters (1931) and Amadon (1942).

As a matter of fact some skins are more vinaceous brown, others more chestnut brown (fat skins?), but this variation is entirely irregular and not geographical. The oldest name for the Australian race is *hilli* (cf. Mathews 1913-1914).

Threskiornis spinicollis (Jameson)

Straw-necked Ibis

Ibis spinicollis Jameson, Edinb. New Philos. J. 19, 1835, p. 213—New South Wales (reference copied).

One specimen (Table VI)

A flock of thirty specimens was habitually present near Millstream Homestead.

Discussion. Peters (1931) placed *fitzroi* Mathews (1912a, p. 228) in the synonymy—this synonym is quoted by Whittell & Serventy (1948,

p. 32) as *fitzroyi*, which would perhaps be right as an emendation, but is incorrect as a quotation of the original description.

Cygnus atratus (Latham)

Black Swan

Several pairs with small and middle-sized young were present on the large pools of the Fortescue River. No specimens were collected.

Anas superciliosa rogersi Mathews

Black Duck

Anas superciliosa rogersi Mathews, Aust. Avian Rec. 1, 1912, p. 33—Augusta, West Australia.

Two specimens (Table VII)

Irides light brown, bill greenish grey, legs greyish brown. The male is in fresh plumage, the female in abraded plumage.

These ducks were common on the Fortescue River and on all other bodies of water of sufficient size.

Milvus migrans affinis Gould

Black Kite

Milvus affinis Gould, Synops. Birds Aust., pt. III, 1838 (April)—Australia.

Milvus aterrimus Gould, Proc. Zool. Soc. Lond. 5, (1837), 25 May 1838, p. 99—nomen nudum.

Milvus korschun napieri Mathews, Novit. Zool. 18, 1912, p. 249—North-West Australia (Napier Broome Bay).

One specimen (Table VIII)

No moult, tail slightly abraded.

Discussion. There is much individual variation in colour in this species and Mathews's *napieri* diagnosed as differing from *affinis* in its darker coloration above and below is doubtless a synonym; it was already listed as such by Condon & Amadon (1954).

Haliastur spheunus (Vieillot)

Whistling Eagle

Milvus spheunus Vieillot, Nouv. Dict. d'Hist. Nat., nouv. ed. XX, 1818, p. 564—Australia (reference copied).

One specimen (Table IX)

No moult, wings fresh looking, tail abraded.

Discussion. No races are admitted by Amadon (1941) and Condon & Amadon (1954).

Aquila audax audax (Latham)

Wedge-tailed Eagle

Vultur audax Latham, Index Ornith., Suppl. 2. 1801, p. 12—New Holland (reference copied).

One specimen (Table X)

Repeatedly observed near Millstream and Tambrey.

Discussion. Peters (1931, p. 256) had already placed *carteri* Mathews in the synonymy, and the fact that Mayr & Rand (1937, p. 19) listed a specimen from New Guinea under a trinomial was probably but a slip, as Mayr (1941b) gives it a binomial again. Quite recently a race has been described by Condon & Amadon (1954) so that a trinomial has now to be used.

Circus approximans subsp.

Swamp Harrier

No material.

Several times I observed a specimen at short range as it was hunting over the water and reed-beds of the Fortescue River at Millstream Station.

Falco berigora subsp.

Brown Hawk

Five specimens (Table XI)

The commonest bird of prey in the area, moreover not shy and easy to collect.

Discussion. Condon (1951a) revised this species but owing to lack of material had to leave the position of the populations of the north-west unsettled. As Condon included in his study only a small part of the material from the Western Australian Museum, I give here the measurements of all our specimens.

South-western Australia [Kojonup, Monger's Lake (Perth), South Perth, Guildford, King R. (Albany), Bridgetown, Canning R., Lake Yanchep, Cottesloe, Bannister, Lake Muir, Peringillup, Herdsman's Lake (Perth), Wandering, Mullalyup, Greenough R. (Geraldton)]:

♂: 305, 306, 307, 315, 341; average (315).

♀: 300, 305, 305, 305, 322, 326, 330, 330, 332, 335, 335, 336, 336; (323).

o?: 304, 305, 328.

Mid-western Australia (Carnarvon, Day Dawn, Dirk Hartog Island):

♂: 309; (309).

♀: 307; (307).

o?: 310.

North-western Australia (Millstream, Tambrey, Point Cloates):

♂: 318; (318).

♀: 331, 341, 362; (345).

o?: 327, 358.

North Central Western Australia (Canning Stock Route):

♂: 321, 326; (323.5).

♀: 314, 342; (328).

o?: 327.

West Kimberley Division (Derby, Brooking Creek):

♀: 355, 365; (360).

When these measurements are compared with those given for the nominate race by Condon (females, wing 360-380, average 371) and Amadon (1941) (whose figures are difficult to interpret because he does not separate males from females) it is evident that birds from south-western Australia are decidedly smaller which confirms the validity of *Falco berigora occidentalis* (Gould). My figures show that as regards size birds of the mid-west fit in with those of the south-west, but that those of the Kimberley Division, as far as one can judge from two skins, are much larger whereas material from the north-west is presumably intermediate in size. Specimens from the Canning Stock Route are smaller. Many specimens in the series are immature and I also suggest that the sexing may have been wrong in a number of specimens. Therefore I prefer not to give a definite opinion on the subspecific status of the birds from the north-west. Condon's revision gives an impression of being a very fine and careful piece of work, but he leaves the status of the birds from north-western and northern Western Australia open, and also I doubt, in view of the apparently complete intergradation that exists, if it is advisable to nomenclatorially recognise quite as many races as he does. Subspecific names have the disadvantage of suggesting discontinuity where in fact continuity exists. Condon (1951a, p. 173) states that: "There do not appear to be good reasons for using the name *Ieracidea* to separate this somewhat aberrant, longlegged falcon generically; osteologically it conforms to *Falco*." Other workers (Condon & Amadon 1954) have denied the validity of the genus *Ieracidea* and even the splitter Mathews

(1915-1916), who in that period often showed very sound judgment, expressed as his opinion that it is hardly worth maintaining. Unfortunately this means that the name of the bird known at present as *Falco moluccensis occidentalis* (Meyer & Wigglesworth) becomes preoccupied by *Falco berigora occidentalis* (Gould); therefore I propose for *Tinnunculus moluccensis occidentalis* Meyer & Wigglesworth (Abh. Mus. Dresden, 1896, Nr. 2, p. 8) the name *Falco moluccensis jungei* nomen novum.

It is not without considerable hesitation that I venture to re-name the Celebes population as according to Mayr (1941a), the name *microbalia* (Oberholser 1917), given to a specimen from Solombo Besar in the Java Sea, may be applicable. As only a single specimen of *microbalia* is known, and the difference between the Java- and Celebes-races is at most rather slight (cf. Smythies 1957) I take the risk of supplying a new name for *occidentalis*. In contradistinction to Mayr, Oberholser (l.c.) considered *microbalia* identical with the Java populations and stressed its difference from the Celebes populations. From the zoogeographic point of view it is most unlikely that the birds from Solombo would be closer to those from Celebes than to those from Java. I may add that if Delacour (1947) is right in giving the range of *javensis* as: "Borneo, Java, Kangean, Solombo-Besar, . . .", the name *microbalia* will have to replace *javensis*. In view of these uncertainties it seems best to accept *microbalia* provisionally as a doubtful endemic race of Solombo Besar.

Falco cenchroides cenchroides Vigors & Horsfield

Nankeen Kestrel

[*Falco*] *cenchroides* Vigors & Horsfield, Trans. Linn. Soc. Lond. 15, (1826), 1827, p. 183—New Holland — Parramatta.

One specimen (Table XII)

A fairly common species, usually seen on the edge of rocky country and open plains.

Discussion. Even Mathews (1915-1916) concluded that no races can be distinguished (although he changed his opinion repeatedly in subsequent publications) but I retain a trinomial as recently Rand (1940) described a race from the highlands of Dutch New Guinea.

The type of *F. unicolor* Milligan in the Western Australian Museum has the whole under surface vinaceous rust colour, whereas in all our other specimens the under surface is largely white; it seems to be an aberrant individual. The wing measurements cannot be taken as the wings have been clipped on both sides; this was already noted by Mathews (1922), who gave a good re-description of the type.

Porphyrio porphyrio subsp.

Swamp Hen

No material.

This species was first recorded by Whitlock (1923) from the reed-beds of the Fortescue River at Millstream though he did not manage to collect specimens. Several times I observed individuals feeding on a mudflat outside the reeds, but they were extremely shy and wary

and although I spent as much time as I could afford trying to stalk them, I failed to obtain any.

The subspecific allocation of this population would be of some interest in view of the fact that Western Australia is inhabited by two very distinct races: *P. p. melanotus* Temminck in the Kimberley Division, and *P. p. bellus* Gould in the south-western part of the state; either might be expected at the Fortescue River. Probably the birds seen belonged to *melanotus*, for, though I had several good views of specimens, I never saw anything of the azureous colour of *bellus*.

Eupodotis australis (J. E. Gray)

Australian Bustard

Only a few specimens were seen on the grass plains of Millstream Station. One bird was taken, but during the night the cats of the homestead managed to get at the fresh skin and destroyed it beyond repair.

Charadrius melanops Vieillot

Black-fronted Dotterel

Charadrius melanops Vieillot, Nouv. Dict. d'Hist. Nat., nouv. ed. XXVII, 1818, p. 139—aux Terres Australes — New South Wales (reference copied).

Charadrius melanops marnngli Mathews, Novit. Zool. 18, 1912, p. 218—North-West Australia (Marnngli Creek).

Two specimens (Table XIII)

Irides sepia, eyelid red, bill, basal two thirds red, tip one third black, legs pink, nails black. Testes of No. A 8286, 7 × 4mm. Neither specimen shows moult. No. A 8286 has a pinkish wash over the belly feathers, whereas A 8285 has the under surface pure white.

Fairly common in suitable places—open shores of lakes and waterholes.

Discussion. Specimens from New South Wales, South Australia, and north-western Australia all agree in colour and measurements, so that *marnngli*, said by its describer to differ in its much paler upper surface, becomes a synonym. Specimens in abraded plumage are somewhat paler above than freshly moulted specimens.

Geopelia striata clelandi Mathews

Peaceful Dove

Geopelia placida clelandi Mathews, Novit. Zool. 18, 1912, p. 186—West Australia (Coongan R.).

Two specimens (Table XIV)

Irides cream, bill brown, legs coral pink.

Common at open places close to Millstream Homestead, but not observed elsewhere, so that, as in other parts of its range, the species is probably more or less confined to settled places.

Discussion. These specimens are more sand colour, less greyish on the upper parts than skins from the Northern Territory and New South Wales; apparently *clelandi* is a fairly well-marked race, as was already pointed out by Mayr (1951).

Geopelia cuneata (Latham)

Diamond Dove

Columba cuneata Latham, Index. Orn., Suppl., 1801, p. lxi—Sydney, New South Wales (reference copied).

Geopelia shortridgei Ogilvie-Grant, Bull. Brit. Orn. Cl. 23, 1909, p. 73—Carnarvon, W. Australia.

One specimen (Table XV)

Common at Millstream in the same habitat as the preceding species, but as a whole less dependent on the presence of man. Early in July we observed several specimens at the middle branch of the Gascoyne River, far away from any human habitation, and collected one male (A 8283).

Discussion. No races are recognisable (Mayr 1951). The name *shortridgei* has usually been neglected, probably (as its describer already suggested) because it is apparently based on a hybrid between *G. cuneata* and *G. striata* (see also Carter 1914). This in itself does not, however, invalidate the name according to the present rules of nomenclature. Names given to "hybrids as such" are not valid, but from the original description it is evident that Ogilvie-Grant did not consider his specimen to be a hybrid as such. As far as nomenclature is concerned, the whole matter of hybrids is apparently still unsettled, and unless and until rules to the contrary may come into operation I propose that *shortridgei* be placed in the synonymy of *G. cuneata*, which saves the junior name *Geopelia placida clelandi* Mathews for its other parent form.

Phaps chalcoptera subsp.

Common Bronzewing

One specimen (Table XVI)

Apparently not common.

Discussion. The material of this species in the collections of the Western Australian Museum is entirely insufficient for working out its geographic variation. The single bird obtained seems not to differ from specimens from the south-western part of the State.

Histriophaps histrionica (Gould)

Flock Pigeon

Columba (Peristera) histrionica Gould, Proc. Zool. Soc. Lond. 8, (1840), May 1841, p. 114—plains of interior of Australia — New South Wales (cf. de Schauen-see 1957).

Phaps histrionica alisteri Mathews, Novit. Zool. 18, 1912, p. 189—North-west Australia (Parry's Creek).

Two specimens (Table XVII)

This nomadic species shows no geographical variation.

Ocyphaps lophotes whitlocki Mathews

Crested Pigeon

Ocyphaps lophotes whitlocki Mathews, Novit. Zool. 18, 1912, p. 191—East Murchison, South-West Australia.

Three specimens (Table XVIII)

Irides orange, bill black, legs coral red, or bill blackish, rim of eye and legs crimson.

Widely distributed in the region, mainly in small bushes in more or less open country (creek beds, etc.).

Discussion. Three specimens from New South Wales in our collection differ from our Western Australian material by the larger white tips of the rectrices; the difference in striation on the scapulars also mentioned by Mayr (1951), is hardly verifiable in my material.

Lophophaps plumifera ferruginea Gould

Plumed pigeon

Lophophaps ferruginea Gould, Handb. Birds Aust. II, 1865, p. 137—Gascoyne River, W.A. (reference copied).

Three specimens (Table XIX)

Irides orange, bare skin round eye red, bill dark leaden, legs black.

Very common at both Millstream and Tambrey.

Discussion. A revision of the species was given by Mayr (1951), who described a new race *proxima* from Hall's Creek Road, Middle Fitzroy River (200 miles up) (type locality) and Margaret River (260 miles from Derby), western Kimberleys.

Our material of the Kimberley Division consists of one specimen from Carlton (close to Victoria River, Northern Territory, the type locality of *plumifera*), two from Moola Boola Station, one from Margaret River, one from Fitzroy River, 200 miles from mouth.

The first four are uniform, more earth colour, less ferruginous, on the upper parts than *ferruginea* and white underneath; they lack the vinaceous wash on the upper parts, which is often present in *ferruginea*. The last mentioned specimen, from the type locality of *proxima*, is slightly more ferruginous above, identical in this respect with *ferruginea*, but retains the white under parts. This confirms the validity of *proxima* (though one might wonder if it is desirable to name an apparently pure intermediate), but contrary to Mayr's conclusion, our material suggests that the Margaret River should be included in the range of the nominate race.

Cacatua tenuirostris sanguinea Gould

Corella

Cacatua sanguinea Gould, Proc. Zool. Soc. Lond. 10, (1842), 1843, p. 138—North Coast of Australia — Port Essington.

Cacatua gymnopsis Sclater, Proc. Zool. Soc. Lond. 1871, p. 490, 493—no certain locality.

Cacatoes sanguinea distincta Mathews, Novit. Zool. 18, 1912, p. 265—Northern Territory (Alligator River, 60 miles inland).

Cacatoes sanguinea subdistincta Mathews, Novit. Zool. 18, 1912, p. 265—North-West Australia (Parry's Creek).

Cacatoes sanguinea apsleyi Mathews, Aust. Avian Rec. 1, 1912, p. 36—Melville Island, Northern Territory.

Cacatoes sanguinea ashbyi Mathews, Aust. Avian Rec. 1, 1912, p. 36—New South Wales (Yanco: according to Condon, 1951b, this is in the interior of Queensland).

Licmetis tenuirostris derbyi Mathews, Aust. Avian Rec. 3, 1916, p. 57—Derby, North-west Australia.

Ducorpsius sanguineus westralensis Mathews, Birds Aust. VI, 1917, p. 211—Murchison, Mid-west Australia.

Ducorpsius sanguineus normantoni Mathews, Birds Aust. VI, 1917, p. 211—Normanton, Queensland.

Two specimens (Table XX).

Irides brown, bill white, legs grey: The weight of specimen no. A 8114 was 550 g. No moult, plumage slightly abraded.

Common near water throughout the area; flocks of hundreds would come to the Fortescue River to drink.

Discussion. Mathews (1916-1917, 1920, 1931, 1946) placed *sanguinea* and *tenuirostris* in different genera, and even an author with sound ideas like Peters (1937) kept them in different sub-genera. Quite recently Vane (1959) came with a revision of the cockatoes, in which *sanguinea* is generically separated from *tenuirostris*, but only subgenerically from *Cacatua roseicapilla*. In all these classifications I cannot see anything but curious survivals from the Linnean bill-and foot-structure classification. I have not the slightest hesitation in reducing *sanguinea* to a subspecies of *tenuirostris*, as the only important morphological difference between the two is the shape and length of the bill. In behaviour and voice the two subspecies (*sanguinea* and *pastinator*) agree thoroughly as my recent field observations on the latter show. Vane's association of *sanguinea* with *roseicapilla* (probably based on von Boetticher's earlier work which is not available to me) is very surprising, for not only in appearance but also in voice the Galah is very different from *sanguinea* and *tenuirostris*. The material of *pastinator* in the Western Australian Museum is very poor but it shows that the southern birds, from Lake Muir, have very long bills, whereas specimens from Morawa and Yalgoo, near the northern boundary of the range, have decidedly shorter maxillae which in fact may be considered intermediate between *pastinator* and *sanguinea* (Fig 2). Bill length in Psittacidae is always somewhat variable, as the culmen continually grows throughout life, and it is through wear that the length of the maxilla is controlled. The difference between the northern and southern subspecies comes down to the fact that *tenuirostris* and *pastinator* have their maxillae less strongly curved than *sanguinea*, so that the tips escape the strong wear caused by the mandible.

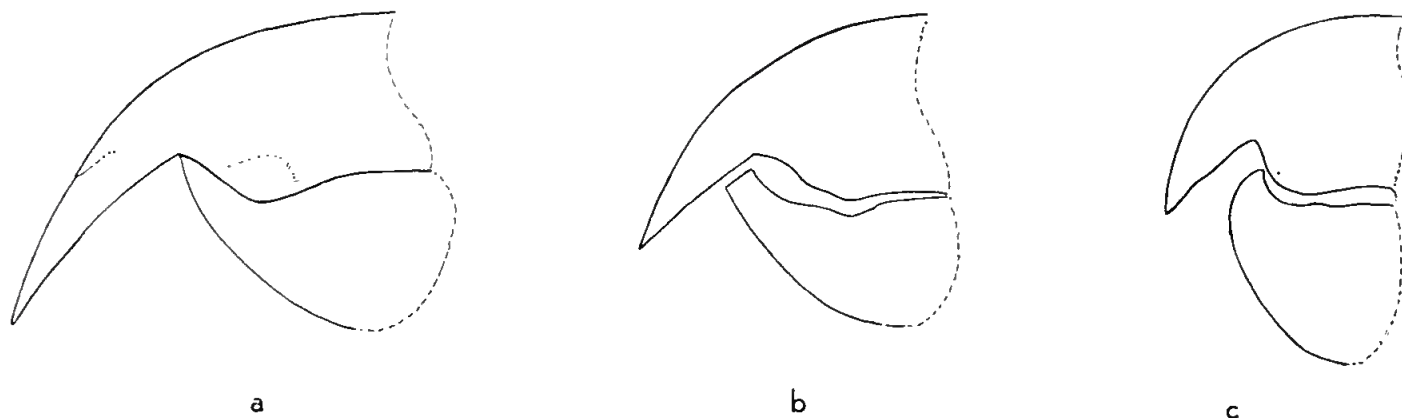


Fig. 2.—Geographic variation in bill-size in *Cacatua tenuirostris*. (a) Male, Lake Muir, 22.I.1916, WAM no. A1163; (b) Male, Ebano, October 1904, WAM no. 6944; (c) Male, Yardie Creek Station, North-West Cape, 8.VIII.1959, WAM no. A8378. Natural size.

The measurements of specimens in the Western Australian Museum collection are:

sanguinea

| sex | loc. | wing | exp. cul. | depth max. |
|-----|----------------|------|-----------|------------|
| ♂ | Cardabia Creek | 260 | 30 | 17½ |
| ? | Broome | 265 | 30 | 16 |
| ? | " | 263 | 32 | 17 |
| ? | " | 275 | 29 | 15½ |
| ? | " | 279 | 33 | 17 |
| ? | " | 280 | 35 | 18½ |
| ? | " | 285 | 34 | 17½ |
| + | Derby | 287 | 32 | 18½ |
| + | Alligator R. | 272 | 34 | 17 |
| + | Eureka | 288 | 32 | 17 |

tenuirostris

| | | | | |
|---|-----------------|-----|----|----|
| ? | R. Murray, Vic. | 230 | 50 | 19 |
|---|-----------------|-----|----|----|

pastinator

| | | | | |
|---|-----------|-----|-----|-----|
| + | Lake Muir | 298 | 45 | 19½ |
| + | " | 312 | 49 | 17 |
| ? | Coorow | 286 | 42½ | 19 |
| + | Morawa | 297 | 43 | 17½ |
| + | Ebano | — | 38 | 18 |
| + | " | 296 | 38 | 18 |

The figures, and comparison of specimens, show that the various races proposed by Mathews for the Northern Territory and Western Australia on size differences do not hold. Condon (1951b) accepted *ashbyi* Mathews as the race occurring in South Australia, and Mathews (1916-1917) stated that *gymnopsis* Sclater was: "based on a cage bird from unknown locality and type lost: I designate Port Essington, Northern Territory." As Sclater expressly identified two specimens from Depot Creek, S.A., with *gymnopsis* it would have been more logical to make this place the type locality. At least in Western Australia, however, I fail to find any difference in measurements between southern and northern birds. The southernmost record we have is an immature male from Mullewa, wing 275 mm, exposed culmen 27½ mm, depth of maxilla 18 mm (A 8330, leg. D. L. Serventy).

With but a single specimen of *C. tenuirostris* at hand I am unable to judge on the validity of *pastinator*, which is supposed to be a larger race with larger wing and bill, but my Victoria specimen has a larger bill than any specimen of *pastinator*, and its wing is not so very small either but falls in the range of variation of *pastinator*. In view of the fact that competent ornithologists like Gould and North accepted the validity of *pastinator*, I provisionally recognise it.

Cacatua roseicapilla roseicapilla Vieillot
Galah

Cacatua roseicapilla Vieillot, Nouv. Dic. d'Hist. Nat., nouv. éd. XVII, p. 12—dans les Indes = New South Wales (Mathews) (reference copied).

Cacatoes roseicapilla assimilis Mathews, Novit. Zool. 18, 1912, p. 266—West Australia (Laverton).

Two specimens (Table XXI).

Irides pinkish red.

The Galah is plentiful in the area, usually seen in flocks of up to a hundred and (rarely) more individuals. They are seen feeding on the ground, or perched in large dead trees, or coming down to water to drink.

Discussion. Recently Mayr (1951) discussed the species, accepting as distinct the race *kuhli* from north-western Australia and the Northern Territory. The four specimens from

Derby in the Western Australian Museum differ from specimens from elsewhere by their slightly paler pinkish coloration, particularly on cheeks, throat, and middle of under parts, thus confirming Mayr's conclusions.

The specimens from the Hamersley area agree with the southern ones, and must be referred to the nominate race; perhaps specimens from New South Wales have the grey of the back on the average darker, but I agree with Mayr that this doubtful difference is not worth nomenclatorial recognition.

Barnardius zonarius occidentalis (North)
Port Lincoln Parrot

Platycercus occidentalis North, Rec. Aust. Mus. 2, 1893, p. 83—Karratha Station, thirty-six miles S.W. of Roebourne, North-west Australia.

Platycercus zonarius connectens Mathews, Novit. Zool. 18, 1912, p. 274—East Murchison, West Australia.

Six specimens (Table XXII).

Irides sepia, bill pale blue-grey, legs blackish; or irides brown, bill grey horn, legs grey. None of the specimens are in moult, some are in fresh plumage, others in more or less abraded plumage.

A rather common bird, though usually seen in pairs, never in flocks.

Discussion. The race *occidentalis* is well characterized by its yellowish green upper parts, pale yellow under parts, blue feathers on the sides of the face, and small size. Birds from the Murchison belong to this race, and the name *connectens* had been rejected by Mathews (1931) himself, though it was resurrected by Cain (1955).

The Western Australian Museum has now over a hundred specimens of this species from Western Australia, which show a most interesting variation, and about which I hope to publish in future. I agree with Condon (1941) that *Barnardius* is a valid genus and should not be merged in *Platycercus* as Peters (1937) did.

Neophema elegans (Gould)
Elegant Parrot

Nanodes elegans Gould, Synops. Birds Aust., pt. II, 1837 (Jan.)—New South Wales and Van Diemen's Land? = South Australia.

Nanodes elegans Gould, Proc. Zool. Soc. Lond. 5, 1837 (21 Nov.), p. 25—In terrâ Van Diemen?

Psephotus elegans carteri Mathews, Novit. Zool. 18, 1912, p. 278—West Australia (Broome Hill).

One specimen from Hooley Station collected by Mr. E. W. Parsons on 13 April 1959, and forwarded to the museum in spirits, no. A 8365.

This is a most interesting discovery as normally the species is confined to the lower south-west of the state. Mr. Parsons shot this solitary specimen from a tree near the home-stand. It is extremely unlikely that the specimen would have escaped from captivity and I consider it to be a straggler. The species is known to be increasing in numbers in the south-west.

Discussion. The race *carteri* was accepted by Peters (1937) and Cain (1955). From the National Museum of Victoria I received five specimens of *elegans* on loan, which I compared with our material from Western Australia, and

I found that the alleged colour differences between the two populations are imaginary. There is no difference in size either as the following figures of the wing-length show:

Western Australia, males: 108, 109, 111, 112, 113, 118. Victoria, three males, two unsexed: 105, 106, 108, 109, 113.

Mathews (1912a, 1913, 1920), Peters (1937), and Whittell & Serventy (1948) all quoted the "P. Z. S." as the original description, but as Mathews (1927, 1946) correctly pointed out, the part of the "Synopsis" in which the species is described was published earlier.

The species does not occur in Tasmania, and Gould was in doubt about the provenance of his first specimens, providing the locality Van Diemen's Land with a query. Of subsequent authors Mathews (1912a) changed the type locality to Victoria, later (1913, 1916-1917, 1920, 1946) to South Australia, (1927) to New South Wales; Peters (1937) followed Mathews (1912a) in deciding on Victoria, whereas Whittell & Serventy (1948) placed the locality "Tasmania" in inverted commas without suggesting a substitute.

Gould (1841) commented on the distribution of the species as follows: "As far as I could learn, the present species is never seen in Van Diemen's Land, . . . neither is it a common bird in New South Wales, its visits to that country being quite accidental. I found it abundant in South Australia, even in the depth of winter and I have since received its eggs from the same country, as well as from King George's Sound and Swan River".

On the other hand, the only definite locality given by Gould in the original description was New South Wales, but until 1836 New South Wales included South Australia. Gould would probably not yet have been able to consider the foundation of South Australia as a separate state in a paper published in January 1837. Therefore I believe it justified to accept as restricted type locality South Australia.

In this connection I would like to point out that the mention of Victoria by Mathews (1912a) does not appear to be a valid restriction, whereas his 1913 publication, where South Australia is definitely substituted, constitutes the first valid restriction of the type locality.

Melopsittacus undulatus (Shaw)

Budgerygah

Psittacus undulatus Shaw, Nat. Miscell. XVI, 1805, pl. 673—New South Wales (reference copied).

Five specimens (Table XXIII).

Irides white, legs blue-grey. None of the specimens shows moult, the outer primaries are slightly abraded.

Several flocks were present at Tambrey.

Discussion. According to Mayr (1951) the species shows no geographical variation.

Cuculus pallidus (Latham)

Pallid Cuckoo

Columba pallida Latham, Index Ornith., Suppl., 1801, p. lx—New South Wales (reference copied).

H [eterocenes] occidentalis Cabanis & Heine, Museum Heineanum IV (1), (1862-63), 1864, p. 27—Westaustralien.

Two specimens (Table XXIV).

Irides brown or sepia, eyerim dark yellow, bill black, basal half of mandible greyish yellow or dirty yellow-brown, legs brown-grey, soles yellow-brown, inside of mouth red-orange. Plumage fresh, no moult.

Fairly common in half open country. The birds were singing.

Discussion. There is no difference in size between specimens from Western Australia and New South Wales, and no difference in colour or colour-pattern either.

Chalcites basalis (Horsfield)

Bronze Cuckoo

[*Cuculus*] *basalis* Horsfield, Trans. Linn. Soc. Lond. 13, 1821, p. 179—Java.

One specimen (Table XXV)

Irides grey, bill brown, legs dark brown, weight 18 g, no moult, plumage slightly abraded.

Apparently rare, I have seen only one very shy specimen (at Tambrey on 5 August). The specimen listed was taken by Mr. Buller.

Ninox novaeseelandiae subsp.

Boobook Owl

Two specimens (Table XXVI).

Irides greyish green, bill blue-grey, tip and tomia dark horn grey, legs light blue-grey.

The Boobook Owl was apparently fairly common near Millstream and Tambrey where it was repeatedly observed; no. A 8361 was taken from a crevice in the rocks, no. A 8362 from a tree.

These specimens are most interesting; A 8362 is very pale, and perfectly agrees with a specimen from Mcda, Kimberley Division, in our collection, and therefore with *arida* Mayr. Specimen A 8361, on the other hand, is very dark, it is streaked, not ocellated, on the under surface, and the streaks are even darker, bolder than in New South Wales specimens. A specimen from Coolawanyah in our collection is almost exactly intermediate between these two, whereas a skin from Marble Bar is identical with *arida*. Incidentally, Mayr (1943, p. 17) mentions a specimen from Marble Bar which is not typical of *arida*.

Evidently the situation needs clarification and therefore I do not, for the moment, assign a subspecific name to my material.

Partial revisions of *Ninox novaeseelandiae* were undertaken by Mayr (1943) and Condon (1951b), but because of lack of time and adequate material these authors had to leave the status of the populations of the central and southern parts of Western Australia unsettled.

Apparently no two authors agree as to how many races should be recognised, and by what they differ. Though I was mainly concerned with applying the correct name to the Western Australian owls, it appeared impossible to do this without some revisional work. Loans of material from the South Australian Museum and the National Museum of Victoria, mainly from the southern half of Australia, enabled me to arrive at a conclusion rather different from any arrangement hitherto proposed. With the material of the Western Australian Museum, about 110 specimens were examined. Practically

no material from Queensland and from western South Australia or eastern Western Australia has been available.

The following races appear to be recognisable in the southern half of Australia.

1. *Ninox novaeseelandiae leucopsis* (Gould)

[*Athene*] *leucopsis* Gould, Proc. Zool. Soc. Lond. 5, (1837), 25 May 1838, p. 99—Van Diemen's Land.

[*Noctua*] *Maculata* Vigors & Horsfield, Proc. Linn. Soc. Lond. 15, (1826), 1827, p. 189—Australia, no precise locality given (preoccupied).

Spiloglaux boobook clelandi Mathews, Aust. Avian Rec. 2, 1913 (29 Dec.), p. 74—Flinders Island.

Spiloglaux novaeseelandiae tasmanica Mathews, Aust. Avian Rec. 5, 1917 (21 July), p. 70—Tasmania.

Diagnosis. A very well-marked race, easily recognised by its small size, dark upper parts with usually many small white dots on the upper surface, especially on the neck, and strongly ocellated under surface.

Distribution. Tasmania and probably islands in the Bass Strait. This race is so distinct that I have no hesitation in referring two birds collected in southern Victoria (Queenscliff, and University grounds, Melbourne) to it. Since I have also examined a specimen "caught at sea 50 miles off the Hunters" in May 1906, I have no doubt that the Tasmanian race is at least partly migratory, which accounts for its occurrence in Victoria. Whether or not it is a resident on the islands in Bass Strait I am unable to say.

Discussion. Mathews (1912d) rejected *Athene leucopsis* Gould as a nomen nudum and stated it to be "probably *Strix cyclops* Gould", subsequently (1931) listing *Athene leucopsis* "Mathews", with *Strix cyclops*, as a synonym of *Tyto n. novaehollandiae*. Neither the fact that this form does not occur in Tasmania, nor the fact that Gould expressly associated his *Athene leucopsis* with the genus *Athene* (= *Ninox*) and not with *Strix* (= *Tyto*) deterred Mathews from this blundering.

Anyway, *Athene leucopsis*, as published by Gould, is not a nomen nudum as Peters (1940) correctly pointed out. Gould's description (1838, p. 99) reads as follows:

"Four species of this genus [*Athene*] are now on the table, the two largest of which are new to science. For the largest I would propose the name of *Athene strenua*, and for the other that of *A. fortis*. The third has been characterised by Messrs. Vigors and Horsfield as the *Noctua Boobook*, and the *Noctua maculata* of these gentlemen seems to be identical with it. For the fourth and last species of the genus, which is from Van Diemen's Land, and which is evidently distinct from either, I propose the name *leucopsis*, from the white colouring of its face. The species of the genus *Strix* which I have called *delicatus* [error for *delicatus*], together with my *Strix cyclops* and *Strix castanops* and the *Strix personata* of Messrs. Vigors and Horsfield, may be said to be closely allied, but distinct species".

The remark about the white colouring of the face validates the name *leucopsis*, whereas from the preceding lines can be inferred that it is a small form. The reason that Gould never republished this name is evidently because he

realised its identity with *Noctua maculata* Vigors & Horsfield. In his later publications Gould always mentioned the white face in his descriptions of *maculata*.

2. *Ninox novaeseelandiae boobook* (Latham).

Strix boobook Latham, Index Ornith., Suppl., 1801, p. xv—New South Wales (reference copied).

Athene marmorata Gould, Proc. Zool. Soc. Lond. 14, 1846, p. 18—South Australia, here restricted to Adelaide.

Spiloglaux boobook leachi Mathews, Aust. Avian Rec. 2, 1913, p. 74—Victoria, restricted to East of Melbourne by Mathews (1915-1916, p. 326).

Spiloglaux boobook tregellasi Mathews, Aust. Avian Rec. 2, 1913, p. 74—Frankston, Victoria.

Diagnosis. A large subspecies which shows some variation in coloration. The darkest extreme, which has been described as *marmorata*, is dark, upper parts only slightly less dark than in *leucopsis* (which race is slightly more chestnut brown); white dots on head and neck, when present, larger, more vaguely defined, than in *leucopsis*. Under surface rather cold brown, more often ocellated than striated. The more typical *boobook* has generally somewhat paler, warmer brown, upper parts, and the under surface in these lighter birds is more often striated than ocellated.

Distribution. The whole of Victoria and New South Wales, southern Queensland, eastern South Australia and southern Northern Territory.

Discussion. There is a certain amount of variation in the range of this race. Dark individuals are found in southern, coastal Victoria, and in the adjacent part of South Australia, whereas specimens from interior localities tend to be somewhat paler. Originally I even thought that it would be possible to distinguish dark individuals as a separate race *marmorata*, but, though there is no doubt that dark specimens are predominant in the area just indicated, rather dark individuals occur also near Sydney (Manly) and even in interior New South Wales, whereas a specimen from Kew, Melbourne, is definitely of the browner *boobook* type. Six specimens from Adelaide belonged evidently to the paler *boobook* type, but three others from the same area (Adelaide, Mile End, Mt. Barker) are darker. It is evident therefore that no discrete geographical area can be assigned to the darker birds, so that it is impossible to regard them as a separate race. Also, though the extremes are fairly distinct, the great majority of individuals are to a varying degree intermediate.

There is in my mind no doubt that the name *marmorata* applies to dark individuals of this race. *Athene marmorata* was described as being: "Nearly allied to *Athene maculata* [= *leucopsis*], but much exceeding that species in size", to which Gould later (1848) added: ". . . much larger than *A. maculata*, but so nearly to, and so much like that species, that I have not thought it necessary to give a separate figure of it". Accordingly I restrict the type locality to Adelaide, where such dark specimens are known to occur.

Mathews's names *leachi* and *tregellasi* are hardly worth comment. The first of these alleged races was described as differing from *maculata* (= *leucopsis*) in its larger size (no comparison

was made with *marmorata*, which was separated from *maculata* on exactly the same character), the second as differing from *marmorata* in its much darker general coloration. Differences between these two alleged new races were not given. The type locality of *leachi* was given as Victoria, that of *tregellasi* as Frankston, Victoria. Two years later Mathews (1915-1916, p. 326)—quoting the original descriptions and, incidentally, falsifying the quotation by these additions—precised the type localities to: "Victoria (East of Melbourne)" for *leachi* and "Frankston, Victoria (North of Melbourne)" for *tregellasi*. It remains only to be said that Frankston is not north of Melbourne, but due south of it on the coast.

It is surprising how, after all this, Mathews (1915-1916, p. 314) could pronounce that: "The typical locality of 'boobook' being New South Wales, comparisons must be made with birds from that locality".

3. *Ninox novaeseelandiae halmaturina* Mathews.
Ninox boobook halmaturina Mathews, Novit. Zool. 18, 1912, p. 254—Kangaroo Island.

Diagnosis. A dark subspecies. Differs from neighbouring dark races by the coloration of the under surface which is striated to ocellated very dark brown, interspaced not with whitish but with rufous cinnamon, a colour also very distinct on the feathers of the legs.

Distribution. Kangaroo Island off the coast of South Australia.

Discussion. This race was synonymized with "*marmorata*" by nearly all recent authors, including Mathews himself. Only Condon (1951b) gave it the benefit of the doubt. My opinion is based on the same two specimens Condon had, but I think that not the dark back and the rather small size are the crucial characters but the colour of the under parts, and as far as one can judge on the basis of two specimens only, *halmaturina* is a valid race.

4. *Ninox novaeseelandiae rufigaster* nova subspecies

Diagnosis. A well-marked race (as already correctly observed by Serventy 1932), which differs from *boobook* by being more rufous underneath: whereas in the eastern specimens the feathers of the undersurface are brown with white edgings, those from the south-west have them brown, outwards gradually changing in rufous and then in white. The size is smaller on an average. The uniformity in the series is remarkable, and among the seventeen specimens examined there is not a single aberrant individual. This uniformity is an additional argument for separately naming the population.

Distribution. South-western Australia, north to Point Cloates and Glen Florrie (Ashburton River).

Type. ♀, 19.VIII.1916, Perth, received from Messrs. Boan Bros. WAM no. A 1022.

Discussion. Whittell & Serventy (1948), probably following Peters (1940), included the birds from the south-west with *marmorata*, and subsequently Condon (1951b) paid attention to these owls; he had not enough material to judge

the validity of the south-western race, but suggested: "that it may eventually be proved that south-western birds are separable under the name *parocellata*".

The names proposed by Mathews now need attention. As Mathews confused this subspecies with *ocellata*, this population long escaped his notice, but in 1946 he proposed "*S[piloglaux] b[oo]book parocellata* nov. South West Australia. Described Birds of Australia Vol. 5, p. 331, as *S. ocellata* Bonaparte", and "*S[piloglaux] ocellata carteri* nov. Mid West Australia. A slightly smaller form of *ocellata*".

The reference under *parocellata* brings us to a description in which the only bird specifically mentioned by Mathews as having been examined by himself is the type of *ocellata*, though quoted from Ashby appear some remarks on a specimen shot at Bayswater near Perth. The description is therefore a composite one, based partly on the type of *ocellata* (which Mathews thought came from Perth) and partly on the specimen from Bayswater. As first reviser I select as type specimen of *parocellata* the type of *ocellata*, which makes the first an objective synonym of the second.

No explanation is given either of the abandonment of the name *novaeseelandiae*, the use of which Mathews propagated in his earlier publications, or of the splitting of the Boobook Owl into two species (*boobook* and *ocellata*), so probably there is no explanation but Mathews's well-known urge for change and nomenclatural upheavals, and it is of little use to comment on this, or on his earlier (1931) classification in which he split the various races into three species, retaining, however, the name *novaeseelandiae* for one of them.

The name *carteri* should probably be rejected as a nomen nudum; I fail to see that the remark that it is "a slightly smaller race of *ocellata*" is a description. If Mathews had written: "smaller than *ocellata*", it might have been acceptable, but as it is now, he does not say what his *carteri* is smaller than (the specimens from the mid-west of Australia are not smaller than those of the north, north-west, and south-west). Actually I strongly suspect that *carteri* is a hypothetical subspecies, not based on actual examination of specimens, but launched just in case the mid-west of Australia might in future be found to be inhabited by a separable population. However, in case doubt might arise as to whether or not *carteri* is a nomen nudum, I restrict the type locality of *carteri* to Marble Bar and propose as neotype the specimen in the Western Australian Museum, no. 9518 (♀, 21.V.1908, Marble Bar) which makes it a synonym of *arida*. Marble Bar is in the north-west of Western Australia, but in the mid-west of Australia as understood by Mathews and thus within the area given as range of *carteri*. The fact that Mathews included *carteri* with his northern species *ocellata* and not with his southern *boobook* may be considered a further proof that *carteri* was intended for pale northern birds and not for dark southern birds by those who take his "description" seriously.

If the name *parocellata* had ever been used to any extent in literature for the form of the south-west, I would have maintained it for that race, but in view of the general inadequacy of the description, and also as the Bayswater specimen mentioned must have been lost with the Ashby collection, I feel that it is much more satisfactory to describe the form of the south-west as a new race, of which the characters have been given above, and a type specimen is available. This course seems particularly justified as the Bayswater specimen was regarded by Mathews as of a variety observed in rare cases.

5. *Ninox novaeseelandiae arida* Mayr.

Ninox novaeseelandiae arida Mayr, Emu 43, 1943, p. 16—Fitzroy River, five miles south-west of Mt. Anderson, West Kimberley District.

?*Ninox ooldeaensis* Cayley, Emu 28, 1929, p. 163—near Ooldea, South Australia.

3[*piloglaux*] *ocellata* *carteri* Mathews, Working List Aust. Birds, 1946, p. 55—Mid West Australia, herewith restricted to Marble Bar.

Diagnosis. The palest of all races. Upper parts tawny olive (Ridgway 1912, pl. XXIX), with some large whitish spots on the wing coverts; under parts very pale, on many feathers only the shafts being brown, the remainder of these feathers being pale buffish or white.

Distribution. West Kimberley Division, also Pilbara District.

Discussion. Whether or not this is a true geographical race remains to be decided; doubtless typical birds, as described above, are very pale, but Mayr (1943) has observed that some specimens from Roebuck Bay, not far from the type locality of *arida*, were much darker. The same pertains to the material from Tambrey, whence (as stated above) one specimen is a typical *arida*, whereas the other specimen is dark. One specimen from Coolawanyah and one from Barromine are intermediate, and one from Marble Bar agrees with *arida* (this is the specimen proposed as neotype for *carteri*). Evidently the status of *arida* remains in need of clarification.

Ninox ooldeaensis Cayley has been placed in the synonymy of *marmorata* by subsequent authors (Peters 1940), but Cayley's (1929) coloured plate makes it evident that it has nothing to do with that form, and is very close to, if not identical with, *arida*. Unfortunately the types of *Ninox ooldeaensis* and *Ninox yorki*, stated by Cayley to be in the Australian Museum, cannot now be found (Keast, in litt., 14.VIII. 1959).

In view of the remoteness of the type locality of *ooldeaensis* from that of *arida* I consider it advisable not to replace the name *arida* by the older name *ooldeaensis* until the type specimen of the latter may turn up and a direct comparison may confirm the supposed synonymy.

Measurements.

N. n. leucopsis

| | | |
|-------------|------|-------------------|
| Tasmania | .... | ♂: — |
| | | ♀: 203, 206, 210 |
| | | ? : 203, 203, 217 |
| King Island | .. | ♂: 198 |
| Victoria | .. | ♂: 219 |
| | | ? : 211 |

N. n. boobook

| | |
|--------------------|--------------------------------------|
| South Queensland | ♂: 233 |
| | ♀: 251 |
| New South Wales | ♂: 238, 240, 243, 244, 244, 248, 250 |
| | ♀: 228, 243, 246, 257, 258, 261 |
| | ? : 235, 240, 245, 245, 252, 252 |
| South Australia .. | ♂: 230, 234, 235, 240, 241, 243, 247 |
| | ♀: 227, 231, 235, 236, 240, 241, 246 |
| | ? : 249, 252 |
| Central Australia | ♂: 233 |
| | ♀: 233, 234, 242, 249 |
| | ? : 233 |

N. n. halmaturina

| |
|--------|
| ♂: 226 |
| ♀: 236 |

N. n. rufigaster

| |
|--|
| ♂: 215, 215, 219, 227, 233 |
| ♀: 226, 228, 228, 229, 230, 230, 231, 236, 237 |
| ? : 227, 230, 231 |

N. n. arida and specimens of doubtful subspecific identity of the Pilbara District.

| | | |
|----------------|------|--------|
| Meda | .... | ♂: 223 |
| Marble Bar | .... | ♂: 230 |
| Barromine Stn. | .... | ♂: 231 |
| Coolawanyah | .... | ♂: 239 |

Aegotheles cristatus cristatus (J. White)

Owlet Nightjar

Caprimulgus cristatus J. White, Journ. Voy. New South Wales, 1790, p. 241—New South Wales.

Two specimens (Table XXVII)

Specimen no. A 8379 has much rufous on head and breast, specimen no. A 8380 has very little rufous.

Discussion. Many races have been described, and even comparatively conservative authors as Whittell & Serventy (1948) and Serventy & Whittell (1951) recognise as many as four races for Western Australia alone.

In order to get some insight in the geographic variation of the species I examined the material from the Western Australian Museum and the National Museum of Victoria, and some specimens from the Queensland Museum, about 60 skins altogether. These included series from different parts of Western Australia, Victoria, and New South Wales, and odd specimens from South Australia, Northern Territory and Queensland. No material from either Tasmania or New Guinea was available. The following characters were examined.

1. Size. No appreciable differences in size occur anywhere in Australia. The measurements given by Rand (1938) show that the New Guinea subspecies, described as being of large size, is well founded.

2. Rufous tone of the feathers. This is a point that has caused more controversy and confusion than any other character because of its great variability. From the material at hand it is evident that the amount of rufous can vary considerably in one population, but on the other hand there is also a distinct geographical trend, as will be discussed below.

3. Colour of upper parts. These are either darker, more blackish, or paler, more sand coloured.

4. Under parts. The extent of dark freckling, which may cover practically the whole under surface, or is confined to the upper breast.

5. Barring of the tail has sometimes been used as a basis for nomenclatural separation, but I found this character to be very variable in specimens belonging to the same population, and it is apparently not of any use, notwithstanding Mathews's (1918-1919, p. 67) allegations to the contrary.

Even though the material is not nearly sufficient for determining all variation, it is evident—as is to be expected in a species with a continuous distribution—that such geographical variation as exists must be gradual and therefore is difficult to express in nomenclature.

Specimens from south-western Australia are very dark above, and dark below, the dark freckles of the under surface extending right down to the vent. None of the 16 specimens shows any trace of rufous in the plumage. To the north and north-east the plumage is similar, but some rufous becomes evident. Specimens from Dalwallinu, Kondinin, Messengers Patch and Coorow have already some rufous on cheeks and collar. A specimen from Naremben, has only the vaguest trace of rufous whereas a specimen from as far north as Cue shows no rufous at all, and agrees with material from the south-west, though it is, like one skin from Dukin, slightly greyer, less blackish above.

Specimens from East Murchison, and north to West Pilbara, are all somewhat lighter, greyer, both above and below (the extent of freckling being reduced) and have always some rufous; a few individuals are in the rufous phase.

Material from Victoria is very close to that from south-western Australia, but 8 out of 12 birds show some rufous, the upper surface averages in series very slightly paler, and the freckles of the under surface are not continued as far down to the vent. These birds are indistinguishable from the specimens mentioned above from the northern part of the south-west (Dalwallinu, Coorow). Material from South Australia and New South Wales fits in with this series, though specimens from interior New South Wales may be slightly paler, greyer above. A specimen from 12 miles south of Charleville, Queensland, agrees with specimens from New South Wales, as do specimens from Proserpine, Dubolla near Rathdowney, south-eastern Queensland, and Charters Towers, mid-eastern Queensland.

Specimens from the Kimberley Division are very different; the upper surface is not blackish but more sand colour, and on the under surface the freckles are very much reduced in number and extent, being confined to the upper breast. A specimen from Cooper's Creek agrees with these specimens in colour of the upper parts, but the freckles of the under surface are more extended. One of the specimens is in the rufous phase.

As regards nomenclature, excluding the populations of Tasmania (*tasmanica*) and northern Queensland (*olivei*), about which I can have no opinion, I believe that the variation described above justifies the recognition of two races.

1. *Aegotheles cristatus cristatus* (J. White). South-west and mid-west Australia, South Australia, Victoria, New South Wales and south Queensland, perhaps also north Queensland. Greyish to blackish above, many freckles below.

2. *Aegotheles cristatus leucogaster* Gould. Northern Territory and Kimberley Division. Sand-coloured (brownish) above, freckles below confined to upper breast. Usually with some rufous coloration.

The rufous phase of the northern form *leucogaster* was described as *rufa*, a name accepted by Mathews (1931), and by Whittell & Serventy (1948), who give it a range: "from southern part of Kimberley Division to the Ashburton River (possibly still farther south), and into Central Australia". Their opinion on the validity of the race is probably based on Mathews's published writings and on two very rufous specimens from the Ashburton river in the collection of the Western Australian Museum. However, in our museum's collection is a specimen from Derby, the type locality of *rufa*, which has no rufous at all and, together with the slightly rufous Mt. Herbert and Tambrey specimens, shows conclusively that there is not such a thing as a rufous race but that these specimens have been correctly considered a rufous phase. A specimen from 100 miles east of Wyndham (Nat. Mus. Victoria), represents the rufous phase of the race *leucogaster* in the material examined.

In many publications the authorship of this and other species described in White's Journal (1790) is ascribed to Shaw. In my opinion this is not justified, for nowhere in that book appears the slightest intimation that White is not fully responsible. Certainly the fact that in the introduction White acknowledges assistance from Shaw and others is not enough to deprive him of authorship!

***Eurostopodus guttatus* subsp.**

Spotted Nightjar

Three specimens (Table XXVIII).

No moult, plumage slightly abraded.

The material available to me is insufficient to discuss the variation of this species.

***Dacelo leachii leachii* Vigors & Horsfield**

Blue-winged Kookaburra

[*Dacelo*] *leachii* Vigors & Horsfield, Trans. Linn. Soc. Lond. 15, (1826), 1827, p. 205—no locality, ex Latham Gen. Hist. IV, p. 11 no. 2: Keppel Bay, Queensland.

Dacelo leachii cliftoni Mathews, Aust. Avian Rec. 1, 1912, p. 37—Carnarvon, West Australia.

Three specimens (Table XXIX).

Irides white, bill dirty white, legs grey. None of the specimens shows moult.

Fairly common in the forest along the Fortescue River. Curiously all the specimens I observed were in the blue-rumped male plumage.

Discussion. Keast (1957b) recognised the race *cliftoni* for the Hamersley area stating that: "This is a distinctive isolate, readily recognisable by its white head. The presence of one or two 'pale-headed' birds in the Derby series indicates that there is a slight intrusion of Hamersley genes to the north", and on another page once more: "... there are two good isolates (*cliftoni* and the New Guinea *intermedia-superflua*) ..."

Personally, I can find little difference between Hamersley and Kimberley specimens. My material consisted of: north-west, 5♂ ad., 1♂ subad.,

3♀; Kimberley Division, 3♂, 4♀; Northern Territory, 1♂, 2♀; Cairns, northern Queensland, 2♀.

The majority of specimens from the north-west (7 out of 9) have pale heads, but 3 out of the 7 Kimberley specimens also belong in this pale headed series (♀, Fitzroy River, 180 miles from Derby, very pale; ♂, same, 200 miles from Derby; ♂, Ord River). The specimen from the Ord River shows that the pale head in the Kimberley Division is not confined to the Derby area where hybridization with southern birds might be expected to occur.

A female from the Ord River, collected at the same place as the male, on the other hand, is the darkest of the whole series. The two remaining specimens from the north-west are as dark on the heads as the dark ones of the Kimberley series, particularly a specimen from Carnarvon (♂ subad.), the type locality of *cliftoni*. The three Northern Territory birds have dark crowns, but the skins from Cairns, Queensland, are slightly paler and agree with the specimen from Carnarvon just mentioned. Specimens from the north-west are on an average slightly darker buff on the under surface than those from the Kimberley Division, but a specimen from Nullagine is as pale below as the palest skins from the Kimberleys. It seems therefore inadvisable to maintain any races on the basis of colour distinctions.

The measurements are as follows.

North-West—

♂: 195, 204 ♂ subad.: 186 ♀: 201, 202, 202+

Kimberley—♂: 190, 193, 194 ♀: 192+, 193, 195, 198

Northern Territory—♂: 195 ♀: 190, 194

Cairns, Queensland—♀: 193, 198

There is therefore a difference in size between specimens of the north-west and those from northern Australia. But according to Keast specimens from southern Queensland are even larger (wing 204-216 mm), whereas for Cairns he gives 197-206. It seems that slight differences in average size exist between various populations, but that certainly no clear-cut distinctions can be made, and therefore I prefer to include all these populations (also *cliftoni*) with the nominate race.

Halcyon pyrrhopygia Gould

Red-backed Kingfisher

Halcyon pyrrhopygia Gould, Birds Aust. II, 1840, pl. 22—the lower Namoi.

Four specimens (Table XXX)

Irides sepia, bill black, lower part of mandible dirty white, legs dark grey to blackish. None of the specimens shows moult; Nos. A 8056 and A 8059 are in fresh plumage, the other two slightly abraded. The juvenile is palest underneath, A 8058 is very ferrugineous on the under surface, and the other two specimens are intermediate. The males have on the wings a distinct violet gloss, which is absent in the females.

The species is well distributed and fairly common in dry open forest. Usually seen solitary.

Discussion. As Keast (1957b) has shown there is no geographic variation in the species. De Schauensee (1957, p. 179) lists the type specimen under a trinomial, but gives no reasons for doing so.

Merops ornatus Latham

Australian Bee-eater

Merops ornatus Latham, Index Ornith., Suppl., 1801, p. xxxv—New South Wales (reference copied).

Merops ornatus shortridgei Mathews, Novit. Zool. 18, 1912, p. 290—Western Australia (Strelley River).

One specimen (Table XXXI)

Irides red, bill black, legs dark grey. No moult, plumage very fresh.

Not common, a few specimens were regularly observed near the Fortescue River, and one was seen on 11 July, at Goola Lake, Roy Hill Station.

Discussion. The differences in coloration which Mathews (1912a) claimed to exist between specimens from New South Wales and Western Australia are imaginary and there is no difference in measurements either.

Mirafra javanica woodwardi Milligan

Bush Lark

Mirafra woodwardi Milligan, Vict. Nat. 18, 1901, p. 18, 26—Onslow, Western Australia.

Five specimens (Table XXXII)

Irides brown, bill, maxilla and tip mandible horny black, remainder of mandible pale brownish, legs flesh colour. All specimens are in fairly fresh plumage, no moult; the gonads were in different stages of development. The female differs from the males by the almost unspotted breast.

Only found on the large flats covered with short soft grasses, where these larks were quite common, but the occurrence of this habitat itself is very patchy. During our stay, the birds were in full song. My observations on the rainy 30th of July were particularly interesting. At my arrival it was dry, and many larks were singing high up in the sky; after a while it started to rain, and the song altogether stopped, the birds coming down to earth. When the rain lessened (but did not stop) song recommenced, but this time the singing birds did not ascend, but remained perched in the tops of trees and scrubs. Of course it is not unexpected that the curious and specialised song-flight would be impaired by rain.

Discussion. These specimens agree with the type of *woodwardi* in the collection of the Western Australian Museum. As Mr. McEvey of the National Museum of Victoria has recently worked over our material and will soon publish a revision of the species, I refrain from further comment.

Petrochelidon nigricans neglecta Mathews

Australian Tree-martin

Petrochelidon nigricans neglecta Mathews, Novit. Zool. 18, 1912, p. 301—North-West Australia, precised as Fitzroy River by Mathews (1920).

Petrochelidon nigricans distinguenda Mathews, Novit. Zool. 18, 1912, p. 301—West Australia (East Murchison).

Four specimens (Table XXXIII)

Irides brown-sepia, bill black, legs dark grey. None of the specimens shows moult. Nos. A 8260 and A 8262 have wide white edges to the secondaries, which are practically absent in the two other specimens, and are also much less glossy on the back; probably a sign of immaturity.

These swallows were somewhat local in occurrence, for the only place where I saw them was at Tanberry Creek, Tambrey Station, on August 1st. There they were quite common, and apparently breeding as two specimens continuously flew in and out the hollow end of a broken dead branch of a gum-tree. Several times I saw specimens drink in flight.

Discussion. The race *neglecta* was described as follows: "Differs from *P. n. nigricans* in its slightly smaller size and duller coloration above, especially on head and back."

Additional specimens from Western Australia in our collection have the following wing-measurements:

♂ Lake Dundas 103, ♂ South Perth 101, ♂ South Perth 100, ♂ Mongers Lake 101, ♀ Mongers Lake 100.

Specimens from New South Wales and South Australia in our collection measure: 0? Orimba 106, ♀ Gosford 105, 0? Adelaide 111.

Additional specimens from New South Wales received on loan from the Australian Museum, Sydney, measure:

♀ Glanmoir, Bathurst 108, ♀ Petersham 110, ♀ Hay 108, 0? Copmanhurst 110, 0? Colo Vale (plumage strongly abraded) 104.

These measurements show that there is a definite difference in size between specimens from New South Wales and specimens from Western Australia (as correctly stated by Mathews); I do not see a difference in coloration above, but, though my specimens from New South Wales are all old and doubtless discoloured, I suspect that this character is invalid and that Mathews's specimens of *neglecta* were immature. Gould (1842), long ago wrote: "The Van Diemen's race are larger in all their ad-measurements . . . than . . . those killed in New South Wales; individuals from the latter locality again exceed in size those from Western Australia."

As specimens from Day Dawn, Perth, etc. do not differ in colour from those of Tambrey and Millstream, *distinguenda* enters the synonymy of *neglecta*. Admittedly I have not seen topotypical material of *neglecta*, but Mathews (1919-1920, p. 50) described a female from West Kimberley as having a wing of 101 mm, which thus agrees with my material. It is interesting to note the absence of a size gradient in Western Australia. Since writing the preceding lines I have received a photocopy of White's (1936) paper. Apart from the fact that I have preferred to use the name *neglecta* rather than *distinguenda*, my classification agrees with that proposed by him.

Mathews (1919-1920) commented on the absence of generic characters of the monotypic genus *Hylochelidon*, nevertheless using this name. Mayr & Bond (1943) placed the species in the subgenus *Petrochelidon* of their genus *Hirundo*. As I do not believe in the use of subgenera, I retain *Petrochelidon* as a genus, an opinion to which, incidentally, Dr. Bond has also reverted (Bond 1956).

Anthus novaeseelandiae australis Vieillot

Groundlark

Anthus australis Vieillot, Nouv. Dict. d'Hist. Nat., nouv. éd. XXVI, 1818, p. 501—Sydney, New South Wales (reference copied).

Five specimens (Table XXXIV)

Irides sepia, bill: maxilla and tip mandibula dark grey (horn), mandibula and tomia maxilla bluish white, legs pale brownish flesh.

Common and widely distributed in open country.

Discussion. I have examined and measured all our material from Western Australia, 63 specimens, and found no geographical variation in size. There is a great range of individual variation in colour, some specimens being very rufous—specimen No. A 8081 from Lake Goola, Roy Hill Station, is an extreme in this respect—but this variation is individual rather than geographical. Hence I agree with Whittell & Serventy (1948, p. 98-99) who have placed *bilbai* Mathews, *subaustralis* Mathews, *subrufus* Mathews, *montebelli* Montague, and *hartogi* Mathews in the synonymy of *australis*.

Lalage sueurii tricolor (Swainson)

White-winged Triller

Ceblepyris tricolor Swainson, Zool. J. 1, 1825, p. 467—Australia (reference copied).

Two specimens (Table XXXV)

Male, irides pale brown, bill black, legs black; female, irides dark brown, bill black, basal two-thirds of mandible yolk-yellow, legs black. Specimen No. A 8112 is a male in change, though it shows no moult in primaries and rectrices, which are new; specimen No. A 8113 shows no moult, the tail is strongly abraded, the wings are slightly abraded.

Only observed in some not very dense scrub country close to the Millstream Homestead.

Discussion. Our material confirms the conclusions of Mayr (1940) and Keast (1958g) that this species shows no geographical variation within Australia.

Coracina novaehollandiae subpallida Mathews

Black-faced Cuckoo-shrike

Coracina novaehollandiae subpallida Mathews, Novit. Zool. 18, 1912, p. 326—North-West Australia, precisised as Strelly [=Strelley] River by Mathews (1921-1922).

Coracina gascoynensis Ashby, Emu 29, 1930, p. 190—Jerrynew Creek or Jacob's Creek, Gascoyne River.

Five specimens (Table XXXVI).

Irides dark sepia-brown or very dark brown, bill black, legs dark grey to black, colour of testes dark slate (very few species of birds have the testes pigmented).

The immature male is in the *gascoynensis* plumage, with the black restricted to the lores, and with a pale throat; this specimen is in strongly abraded plumage, no moult. The other specimens are in fairly fresh plumage, with only their tails somewhat abraded.

Widely distributed and common wherever there are trees. Nearly always seen in pairs, but sometimes several together.

The race *subpallida*, confined to the north-west differs from all other forms by its paler grey mantle. Though the difference from other

populations is not very striking, it is quite constant and every single individual can be picked out on the basis of this character. Mathews (1912a) incorrectly included the Kimberley Division and the Northern Territory in the range of *subpallida*.

Keast (1958g) has revised the species but as my conclusions differ somewhat from his, I give a full discussion of all the material in the Western Australian Museum.

First I want to point out that if it is correct to recognise a separate race for the northern part of Australia, this should not bear the name *didima* Mathews (1912b) but should be known as *connectens* Mathews (1912a), type locality Inkerman, Queensland, which has priority. This bird was described as slightly smaller than *novaeollandiae* (though Mathews did not give a single measurement) and therefore probably belongs to the northern population, and is not a migrant from the south where specimens average slightly larger (cf. Keast 1958g, Table I). It is nowadays custom to name specimens collected in New Guinea, Timor, Soemba, and the Moluccan Islands *didima* (Mayr 1941b, Mayr 1944, van Bemmelen 1948, Gyldenstolpe 1955).

However, I do not consider it advisable to recognise a northern race at all. Keast claims that the specimens of the south-west have small bills, and that those from the north, including the Kimberley Division, are large-billed, and his figure 1 gives an exaggerated picture of this, showing the Kimberley bird with a bill of at least twice the bulk of the south-west bird. My measurements show that the difference in bill-size is slight.

| No. of specimens | Location | Ent. cul. | Exp. cul. | Cul. nostr. |
|------------------|-----------------------------|-----------------|-----------------|-----------------|
| 14 | S.W.A. | 25-30 (27.1) | 20-23 (21.3) | 16-19 (17.6) |
| 5 | Kimberley Division and N.T. | 27-32 (29.7) | 22-25 (23.5) | 18-20 (19.3) |
| 1 | N.S.W. | 29 | 24 | 19 |

I cannot possibly consider this difference in average size of the bill to be of subspecific value, particularly as one sees the great variation in bill size (not only length, but also width and depth) in birds from the same region. Therefore I include the birds from the northern half of the continent in *melanops*.

The objection might be made that some of the Kimberley birds I measured may have been migrants from the south. The migrations are still far from well known, and the last word about them has certainly not yet been spoken or written. But there is the evidence that neither Keast nor I found any specimens of *melanops* in the range of *subpallida*, and that, on the other hand, we never found a specimen of *subpallida* outside its accepted breeding range. This strongly points to these populations being largely sedentary.

The specimens not rarely recorded from the Lesser Soenda Islands, Moluccas and New Guinea have always been considered migrants from Australia, and it is custom to call them *didima*, thus identifying them with populations

from northern tropical Australia. This again, is very unlikely; migrants would be expected to belong to the southernmost populations of the species (Tasmania, southern Australia), but never to the northern tropical populations. On the other hand Tubb (1945) found specimens attending fledglings near Port Moresby which suggests that *C. novaeollandiae* is not a migrant but at least partly a resident in southern New Guinea, and links it up with the populations of northern Australia.

Certainly the measurements of the specimens recorded from New Guinea (Mayr & Rand 1937, p. 100; Junge 1939, p. 4; Gyldenstolpe 1955, p. 269) are rather small, none reaching 200 mm; actually they are lower than those of any specimen measured by Keast, but as Junge states, many specimens are very worn which explains the small wing measurements.

I have not seen adequate material from Tasmania, but at least the differences in measurements between Tasmanian and Australian specimens as tabulated by Keast, seem very slight, and hardly worth stressing by nomenclatorial separation. Lack of literature unfortunately also prevents me from checking if Mathews was justified in restricting the type locality of the species to Tasmania.

Additional measurements of specimens in our collection.

subpallida: ♂: 182, ♀: ?; 198.

South-western Australia:

♂ ad.: 192, 192, 201, 207, 208, 210, 211, 216.

♂ imm.: 199.

♀ ad.: 201, 207.

♀ imm.: 189, 197.

? ad.: 202.

? imm.: 190, 196.

Kimberley Division:

♂ ad.: 193, 199.

♀ ad.: 187.

♀ imm.: 186.

? imm.: 182.

New South Wales:

♂: 207.

Mayr (1941b) lists three races of *Coracina novaeollandiae* as wintering in New Guinea: *novaeollandiae*, *melanops*, and *didima*, but how these races were identified he does not explain. Earlier Mayr & Rand (1937), and later Rand (1942), wisely refrained from giving their material a subspecific name.

Why Voous & van Marle (1949, Fig. 5) excluded south-western Australia from the range of the species is not clear to me, anyway it is incorrect. Many of the zoogeographical hypotheses brought forward by these authors seem to me highly speculative, but a discussion of the zoogeography of the species falls outside the scope of this paper.

Pomatostomus temporalis rubeculus (Gould)

Grey-crowned Babbler

Pomatostomus rubeculus Gould, Proc. Zool. Soc. Lond. 7, (1839), March 1840, p. 144—North-west coast of Australia = King Sound, W. Kimberley Division.

Pomatostomus temporalis nigrescens Mathews, Novit. Zool. 18, 1912, p. 335—North-West Australia (Strelley River).

Pomatostomus innominatus Mathews, Birds Aust., suppl. no. 3, add. and corr., 1924, p. 223—Point Torment, North-west Australia.

Two specimens (Table XXXVII).

Irides light grey with above the pupil a brown spot; bill black, lower half of mandible bluish white; legs dark grey. No moult, plumage slightly abraded.

Not very common but widely distributed in the region in the well-wooded river valleys, where living in small parties of from two to four birds. The birds are rather shy and move fast from tree to tree, hence they are not easy to collect. They draw attention by their cat-like mewling calls. Besides Millstream I have observed the species at Wittenoom and Dale Gorge Creek.

Discussion. Deignan (1950) revised the species, accepting, to use his own words, a "quite surprising" number of subspecies. Condon (1951b) commented upon this and wrote: "From a representative series from Northern Australia from all parts, except the areas assigned to the recently described races *browni* and *mountfordae*, I have been able to distinguish only the following: *rubeculus* (synonym *bamba*), *nigrescens*, and *intermedius* (synonym *innominatus*)." Mack (1953) thought that at least *rubeculus* and *nigrescens* are valid races.

The Western Australian Museum has one specimen from the Northern Territory (South Alligator River) and fair series from various localities in the Kimberley Division and the north-west; in addition four specimens from the Northern Territory have been received on loan from the Australian Museum. In this material, the specimens from the north-west are darkest on the upper surface; those from the Kimberley Division average slightly paler which, however, is discernible only when series are compared for many individual specimens are inseparable, whereas the Northern Territory birds are definitely paler above. Unfortunately the Northern Territory specimens are old and faded, and the material also shows that birds in abraded plumage are paler above than freshly moulted specimens. Condon's suggestion of differences in bill-size is not confirmed by my material. It is significant that our two specimens from the Fortescue River, collected at the same date and locality, show a difference of more than 5 mm (about 20%) in length of the exposed culmen. Both are fully adult birds*. The amount of creamy white coloration on the head is variable, some specimens in the north-west have the brown-grey median stripe on the crown very much reduced, and others have it broad. In all our Kimberley skins the brown-grey is well developed, as in the majority of north-west birds.

As far as nomenclature is concerned, I consider that Kimberley birds should be united with those from the north-west, whereas the paler backed populations from the Northern Territory deserve their own name. The applicability of the name *rubeculus* for the birds from Western Australia will be discussed below.

Deignan (1950) advocated the opinion that *Pomatostomus* occurs in isolated populations but this is contrary to my experience expressed

* I can have no opinion on the races *mountfordae* and *browni*, described by Deignan on size of bill, but the fact that not a single measurement of either bill or wing is given in his paper does nothing to enhance confidence in the validity of these new forms.

above that they are very mobile and energetic birds, present wherever there is suitable habitat. (wooded river beds).

Mathews designated as type locality Port Essington, but this is incorrect. This and a number of other new species were described by Gould (1840) in a letter dated May 10th, 1839. Of the species described, thirteen are stated to have come from the north-west coast of Australia, and twelve of these are acknowledged to have been received from Benjamin Bynoe, surgeon of the "Beagle," whereas with the thirteenth, *Malurus cruentatus*, no particulars as to collector or donor are given, but it may safely be assumed that this specimen was also brought back by the Beagle.

Though Mathews is right that Bynoe and the Beagle visited Port Essington, it is equally true that this visit took place only in the second half of 1839. In 1838 and early 1839 the ship had been surveying the western and southern coasts only, the west coast north to Brunswick Bay and Augustus Island (Stokes 1846) in what is nowadays the West Kimberley Division, and it is evident that the new birds must have been obtained there, probably at King Sound, where the Beagle stayed for some time. This causes a number of changes in the type localities as designated by Mathews. I list here the thirteen species concerned, with their type localities as given by Mathews (1931).

| | Name | Type locality according to Mathews | True type locality |
|----|--------------------------------------|------------------------------------|-----------------------------------|
| 1 | <i>Podargus phalaenoides</i> | Port Essington | West Kimberley Division |
| 2 | <i>Pachycephala lunoides</i> | Derby | do. |
| 3 | <i>Malurus cruentatus</i> | Port Essington | do. |
| 4 | <i>Pardalotus uropygialis</i> | Port Essington | do. |
| 5 | <i>Amudina annulosa</i> | Cobourg Peninsula, N.T. | do. |
| 6 | <i>Amudina uenticulata</i> | Derby | do. |
| 7 | <i>Myzanthu lutea</i> | Derby | do. |
| 8 | <i>Troglodytes argenteiceps</i> | Port Essington | do. |
| 9 | <i>Pomatostomus rubeculus</i> | Port Essington | do. |
| 10 | <i>Phylloscopus flavescent</i> | Derby | do. |
| 11 | <i>Myzomela erythrocephala</i> | Port Essington | do. |
| 12 | <i>Sittella leucophaea</i> | Port Essington | do. |
| 13 | <i>Hemipodius castaneus</i> | Port Essington | Swan Point, W. Kimberley Division |

I have not, as being outside the scope of the present paper, checked on the correctness of all other restrictions and designations of type localities made by Mathews, but want to draw attention to one more: *Petrophassa albipennis*, erroneously referred to as *Petrophila albipennis* by Stokes (1846, p. 111), was first collected at Swan Point at the entrance of King Sound, and the type locality Wyndham (Mathews 1912b, p. 28) is quite fanciful.

Mathews's reasons for recording so many species as originating from Port Essington were given by him (Mathews 1925, p. 23) but as I have tried to make clear above, Bynoe's visit to Port Essington took place only in the second half of 1839. Many of his later specimens undoubtedly did come from Port Essington, but not the ones described in Gould's letter of May 1839.

It will be noted that in de Schauensee's (1957) paper on Gould's type specimens in the Academy of Natural Sciences of Philadelphia two cotypes of *Amadina annulosa* are stated to be labelled "Port Essington," and that both alleged cotypes of *Pardalotus uropygialis* are from Port Essington. In my opinion this conclusively shows (unless a mistake in labelling was subsequently made) that these specimens are not cotypes. In the case of *Amadina annulosa*, the third specimen from north-west Australia is probably a cotype and quite conceivably the holotype; in the case of the *Pardalotus* it would seem that the type is not in Philadelphia, it may be lost.

I may add that in my opinion Port Essington can hardly be said to be situated on the north-west coast of Australia.

Fortunately the consequences for nomenclature of this correction of type localities are slight as in the majority of cases the King Sound area and the Cobourg Peninsula have the same race. In a few cases, as in that of *Pomatostomus temporalis*, a shift is necessary, which will result in nothing more serious than a regrouping of a number of Mathewsian synonyms.

Acrocephalus stentoreus gouldi Dubois

Reed Warbler

Acrocephalus gouldi Dubois, Syn. Av. I, 1901, p. 369—nomen novum for *Calamoherpe longirostris* Gould, nec *Turdus longirostris* Gmelin, Syst. Nat. Ed. XIII, I, 1788, p. 823 = *Acrocephalus cafer longirostris* (Gmelin).

Five specimens (Table XXXVIII).

Irides light brown or grey-brown, maxilla black or horny grey, tomia and mandible pinkish white, or fleshy bluish, white at base; legs leaden grey, inside of mouth bright orange. Plumage of the collected specimens fairly fresh, no moult.

Common in the reed beds along the Fortescue River and at the Mill Stream.

Discussion. The Australian reed warblers have been revised by Mayr (1948), whereas subsequently Stresemann & Arnold (1949) have shown that *A. stentoreus* and races is specifically distinct from *A. arundinaceus*, a conclusion confirmed by Zahavi (1957).

Five specimens (4♂, 1♀) from New South Wales (Long Bay, Sydney, Macqueen River) received on loan from the Australian Museum measure: wing, 72, 73, 75, 76, 77; tail, 59, 61, 64, 66, 66; tarsus, 24, 24½, 24¾, 25, 25¼; entire culmen, 19, 19, 19½, 20, 20; exposed culmen 13½, 13¾, 15, 15, 15¼; culmen from anterior point of nostril 10½, 11, 11, 12, 12. Two females from Brisbane, received on loan from the Queensland Museum measure: wing, 71, 74; tail, 59, 65½; tarsus, 24, 25; entire culmen, 19¾, 20; exposed culmen, 13, 14½; culmen from anterior point of nostril 11, 11 mm. This shows that there is not much difference in size from *gouldi*, though the western subspecies runs somewhat heavier in the bill.

As regards possible differences in colour I can say little because specimens evidently fox badly in collections, and all the available material of *australis* and most of that of *gouldi* from the South-West was collected over fifty years ago. Our fresh specimens of *gouldi* differ from old material of both *gouldi* and *australis* by their

much browner, almost chestnut, upper parts, and the darker rufous rump and flanks. Old material is much paler underneath, and the upper parts become duller, more greyish brown, ultimately even with an olive-greyish tone.

Until series of fresh skins are compared it will be difficult to ascertain if *gouldi* can really be separated satisfactorily from *australis* on the basis of colour characters, and if this is not the case, whether or not the slight difference in size would justify retention of the name *gouldi*. Tentatively, and until this point has been cleared, I follow Mayr in accepting *gouldi*.

Mayr (1948) suggested that specimens from the north-west (Strelley River) might differ from topotypical *gouldi* by their more rufous flanks and greyer upper parts. Lack of material from the area prevented him from arriving at a definite conclusion. I am unable to arrive at a conclusion for similar but opposite reasons—lack of fresh specimens from the south-west. The scanty material available, however, points to their being identical (7 specimens from the north-west compared with four from the south-west (Claremont and Lake Yanchep)); greyish olivaceous upper parts as noted by Mayr in birds from Strelley River are doubtless the result of foxing.

Mayr demonstrated that the populations from New Guinea which he (Mayr 1941b) previously included in *australis*, are subspecifically separable, and he accepted the name *cervinus* De Vis (1897) for them, though noticing that the measurements as given in the description of this bird are: "impossibly large for a New Guinea specimen, but De Vis measurements have often been found to be wrong. A re-examination of De Vis' type in the Brisbane Museum would be highly desirable."

Subsequent examination of the type specimen of *Acrocephalus cervinus* De Vis revealed that, in fact, it is a honeyeater and that the name is a synonym of *Timeliopsis griseigula fulviventris* (Ramsay) (cf. Iredale 1956, p. 152). Therefore the race named *Acrocephalus arundinaceus cervinus* by Mayr (1948, 1955) and by Meinertzhagen (1954) should be known as *Acrocephalus stentoreus sumbae* Hartert (I follow Mayr's arrangement of subspecies without own investigation).

In Meinertzhagen's map 13, giving the distribution of the species *A. arundinaceus*, *A. orientalis* and *A. stentoreus* (which Meinertzhagen insists on calling one species, notwithstanding the presence of biological evidence to the contrary), an error is made in the distribution of the race "*cervinus*", as Soemba, the type locality of *sumbae*, is excluded from its range.

Cisticola exilis lineocapilla Gould

Fantail Warbler

Cysticola lineocapilla Gould, Proc. Zool. Soc. Lond. 15, 1847, p. 1—Port Essington.

Two specimens (Table XXXIX).

Irides grey, bill brown, legs pale brown. No apparent moult.

Our comparative material is insufficient but I see no reason not to consider the Millstream specimens to belong to *lineocapilla* described from Port Essington; they agree reasonably well

with specimens from Derby en Eureka, Northern Territory (one of each locality). Lynes (1930, p. 194) repeats the old error, perpetuated by Chasen (1935) and Stresemann (1939, p. 323 Fig. 4) that in Java this subspecies is confined to the eastern part of the island, though it is even known from Oedjoeng Koelon, the western extremity of Java (Hoogerwerf 1948). I have observed individuals on many occasions in the western half of West-Java, where the species is quite common. As Salomon Müller has, as far as I am aware, never visited eastern Java, the type of *Cisticola delicatula* mentioned by Lynes (p. 627) probably has been collected in western Java.

It is also a curious slip from this meticulous author, that he suggested the type to be lost as it was: "not in any of the museums in England." It seems hard to believe that he would have been unaware of the fact that nearly all Gould's types went to the Academy of Natural Sciences of Philadelphia, where the type of *lineocapilla* remains, fortunately, preserved (de Schauensee 1957).

Gerygone fusca fusca (Gould)

Western Warbler

Psilopus fuscus Gould, Synops. Birds Aust., pt. IV, 1833 (April), pl. [61], Fig. 2—Australia: locality uncertain = Swan River, restricted by Mathews (1919-20).

Psilopus culicivorus Gould, Proc. Zool. Soc. Lond. 8, (1840), 1841, p. 174—Western Australia.

Gerygone culicivora wayensis Mathews, Novit. Zool. 18, 1912, p. 338—Mid Westralia (Lake Way).

Three specimens (Table XL).

At Tambrey not uncommon in the gum trees along creek beds.

Mathews (1919-20) transferred the name *fusca* from the form of New South Wales now known as *Gerygone igata richmondi* (Mathews) to the present species, restricting its type locality, given as Australia in the original description, to Swan River. Since Gould (1838) made special mention of the white on the base of the tail feathers, which is apparently absent in *richmondi*, it seems that Mathews was right, and the change has been generally accepted. Nevertheless it seemed interesting to try and trace the type specimen. According to Meise (1931) the type is in Philadelphia, but this is incorrect, as the type specimen was not part of the Gould collection, but belonged to the Earl of Derby. However, in the collection of the Liverpool Public Museums, Mr. Wagstaffe (in litt., 7.IX.1959) has not been able to trace the specimen, so that its whereabouts (if it is still extant) remain unknown to me.

Whittell & Serventy (1948) list the birds from Western Australia under the name *Gerygone fusca culicivora*, but since *culicivora* has become, as a consequence of Mathews's restriction, topotypical of *fusca*, this name cannot stand.

The present specimens, as also material from Day Dawn and Payne's Find, agree in every respect with specimens from Garden Island and the Perth area, hence *wayensis* also enters the synonymy of the nominate race, to which it was already referred by Meise (1931). As our museum has no material from the Kimberley Division. I cannot discuss the status of the forms described by Mathews from that area.

Smicrornis brevirostris mathewsi S. A. White Weebill

Smicrornis brevirostris mathewsi S. A. White, Trans. Roy. Soc. S. Aust. 39, 1915, p. 749—Wantapella Swamp, Central Australia.

Five specimens (Table XLI).

Irides yellowish white, bill pale dirty flesh colour, legs dark dirty flesh colour.

Common throughout the area.

Discussion. The three races occurring in Western Australia are very distinct: *flavescens* in the Kimberley Division, with deep yellow under parts, light upper surface and brownish head; *mathewsi* in the mid-west and North-west with pale under surface, light upper parts (slightly darker than *flavescens*) and greyish brown head, and *stirlingi* in the south-west with dark upper parts.

I have not seen material from Central Australia and follow Keast (1958f) in assigning the specimens from the mid-west to *mathewsi*, though they do not agree very well with the description of that race.

Whether or not the monotypic genus *Smicrornis* is really worth recognition as distinct from *Gerygone* is a question I prefer to leave undecided for the moment. As *Smicrornis* has been used for over a century, it seems advisable to maintain it for the sake of stability.

Cincloramphus mathewsi mathewsi Iredale

Rufous Songlark

Cincloramphus rufescens mathewsi Iredale, Bull. Brit. Orn. Cl. 27, 1911, p. 97—Yalgoo, West Australia (reference copied).

Cincloramphus mathewsi alisteri Mathews, Novit. Zool. 18, 1912, p. 339—East Murchison, West Australia.

Four specimens (Table XLII).

Irides sepia to brownsepia, maxilla horny grey or brownish horny, mandible bluish white, legs dirty greyish flesh or pale pinkish grey. None of the specimens is moulting, their plumage is fairly fresh.

At Millstream Station, where these birds were common, they inhabited a very special biotope, they occurred in open country near the forest edge, with dispersed scanty-leaved or dead trees. These trees they freely used as perching places, and to commence and conclude their song-flights.

Discussion. These specimens agree with material from the Yalgoo district (type locality). There is no doubt that *alisteri* is a synonym. Lack of material prevents me from discussing the other subspecific names given by Mathews; the retention of a trinomial may be unjustified.

Eremiornis carteri North

Spinifex Bird

Eremiornis earteri North, Vict. Nat. 17, 1900, p. 79—North-west Cape, North-west Australia.

Eremiornis earteri assimilis Montague, Aust. Avian Rec. 1, 1913, p. 181—Hermite Island, Monte Bello Group.

Eremiornis carteri rogersi Mathews, Aust. Avian Rec. 1, 1913, p. 192—Hall's Creek, Kimberley Gold Fields (North-west Australia).

Seven specimens (Table XLIII).

Irides brown (fairly light), bill, upper black, lower blue-grey, legs grey to blackish. None of the specimens shows moult.

With one exception, these specimens were taken in a growth of very high and rich clumps of *Triodia*, interspersed with *Acacia* and *Cassia* shrubs, a habitat to which the species is apparently restricted. Though the vernacular name Spinifex Bird is used for it, pure *Triodia* is probably not inhabited. Contrary to many other skulkers of the undergrowth, these birds are easy to collect as they behave very quietly and often remain perched in the same place for a considerable time. To locate the inconspicuously coloured birds, however, is for the same reason difficult. The only call I heard was a moderately loud short: "tk . . . tk . . .", probably the alarm-note. Mathews (1921-1922) depicts a bird of the species with strongly cocked tail, and perched on the ground. I have never seen specimens with the tail so strongly cocked, nor seen them perched on the ground; they were always sitting on branches.

Discussion. I have not seen material from Hermite Island, but the Barrow Island population is usually included with the race *assimilis* by those who recognise that form. As I have been unable to detect any difference at all between the specimens from Tambrey and a series of seven from Barrow Island and two from Thevenard Island off Onslow collected in September 1958, I reduce *assimilis* to synonymy. In this connection it is also worth noting that Montague described his race as smaller than the mainland form, wing-length 53-58 mm: these measurements perfectly agree with those of the Tambrey birds. Mathews (1931), in what is usually considered his best list, placed *assimilis* in the synonymy, though he upheld *rogersi*.

A specimen from the Fitzroy River, 200 miles inland, in our collection, which is almost topotypical of *rogersi*, agrees with *carteri* and is not "much more reddish above" as it should be if *rogersi* were valid.

I have not seen *queenlandica*, but until the validity of that race has been confirmed I prefer to use a binomial for the species.

***Amytornis striatus whitei* Mathews**

Striated Grass-Wren

Amytornis whitei Mathews, Bull. Brit. Orn. Cl. 25, 1910, p. 34—Coongan R., North-western Australia.

Eight specimens (Table XLIV).

Irides brown or sepia, bill dark grey or black, legs grey or blackish grey. None of the specimens shows moult, but they are all in abraded plumage. The feathers are very soft, and combined with the skulking habits of the species, abrasion must be strong. The wings are short and rounded; there are strong black bristles at the gape.

Besides the specimens listed, two juveniles were taken (A 8162, A 8163). After shooting the old birds A 8160 and A 8161, Mr. Buller found them running over the ground between the spinifex, unable to fly, and collected them by hand. Evidently the nos. A 8160-63 formed a family party.

I have not seen the species at Millstream, but at Tambrey it was not uncommon in its special habitat: rocky ridges in spinifex country. They

are very skulking in habits and therefore difficult to collect. No. A 8165 was taken out of a pair, when both birds were hopping, with cocked tails, on the bare ground between clumps of *Triodia* at the edge of a stony ridge. The alarm-call of the species is a rather powerful: "tchèrr . . . tchèrr . . ."

The species was revised by Keast (1958b), who recognised two races in Western Australia, *whitei* and *oweni*, and synonymized *Amytornis rufa* A. J. Campbell & Kershaw with the latter, though he did not examine specimens from near the type locality of *rufus**.

In the collection of the Western Australian Museum there is a series of ten specimens from Well 48 on the Canning Stock Route, the northernmost locality whence the species is known and not far from the type locality of *rufus*. In order to obtain an overall picture of the variation of the species in Western Australia I borrowed an additional five specimens from Borewell, East Murchison, topotypes and paratypes of *oweni*, from the American Museum of Natural History.

The measurements of all these specimens with the averages for the three populations are given in Table XLIVa.

Though the series are very small, the figures suggest that in size *oweni* is intermediate between *whitei* and *rufus*.

In coloration *oweni* is also intermediate; *rufus* has black lines bordering the white striae on the feathers on the forehead only; *oweni* has them over the whole crown, and vague but present on the whole mantle; *whitei* has them distinct and pronounced on the whole upper surface. The general coloration of the upper parts is red-brown in *whitei*, rusty-brown in *oweni*, and rusty-brown almost as *oweni* but on an average a little paler, in *rufus*. On the breast *whitei* has distinct longitudinal striae, *oweni* has these streaks much feebler, *rufus* lacks them altogether though in a few specimens they are faintly indicated. On the under surface, particularly the vent, *whitei* is somewhat darker ferruginous than the other forms.

To make sure that my identification of the Canning Stock Route specimens with *rufus* was correct, I sent some specimens to the National Museum of Victoria in Melbourne, where Mr. McEvey compared them with the type and paratype of *rufus* and also with specimens of *oweni* and *whitei*. Mr. McEvey found much variation in coloration of upper parts, the paratype being darker than the type, but both specimens have the: ". . . black edges to the central shafts entirely lacking except on the forehead"; this settles the question of the identity of the Canning Stock Route specimens. It is interesting that a specimen from Central Australia (R 9985) appeared to agree with *oweni*, thus confirming Keast's opinion. This is the specimen taken by the Horn Expedition at Alice Well and reported upon by North & Keartland (1896, p. 79) and subsequently by A. G. Campbell (1927, p. 31, no. 47). Campbell regarded this specimen as *rufus*.

* Though this form was described as *rufa*, the gender of the genus *Amytornis* is usually regarded as masculine, and consequently the name is here emended to *rufus*.

A specimen from Mt. Kintore in the Musgrave Ranges, examined by Keast (1958b) also agreed with *oweni*.

Originally I had intended to suppress the name *oweni* as a pure intermediate (and to place it as a synonym of *whitei* in order to save the junior name *rufus* for the northern population), but in view of the apparent wide distribution of this intermediate population it seems preferable provisionally to recognise it—at least until the ranges of the various forms have been worked out more satisfactorily—a course also suggested by Mr. McEvey.

Therefore I recognise in Western Australia the following races:

1. *Amytornis striatus whitei* Mathews. Confined to the region generally known as the north-west.

2. *Amytornis striatus oweni* Mathews.

Amytornis striatus oweni Mathews, Bull. Brit. Orn. Cl. 27, 1911, p. 48—East Murchison.

East Murchison and southern Northern Territory.

3. *Amytornis striatus rufus* A. J. Campbell & Kershaw.

Amytornis rufa A. J. Campbell & Kershaw, Emu 12, 1913, p. 274—Lat. 19° 27", about 160 miles north of N.T. Survey Camp C IV (cf. Mathews 1922-1923, on this locality).

Canning Stock Route (Wells 35 and 48) and adjacent part of the Northern Territory (Tanami region).

***Stipiturus ruficeps* A. J. Campbell**

Rufous-crowned Emu-Wren

Stipiturus ruficeps A. J. Campbell, Vict. Nat. 15, 1899 (Jan. 12), p. 116—North-West Cape.

Six specimens (Table XLV).

Irides brown, dark brown, or sepia-brown, bill black, base of mandible and tomia paler, legs light brown. The specimens are in somewhat abraded plumage and two (Nos. A 8222 and A 8223) show tail moult.

Not uncommon at Tambrey, but the population is evidently not dense. This emu-wren is known as a spinifex-bird, and that is correct, but its optimum habitat is where spinifex (*Triodia*) is interspersed with a few small shrubs (*Acacia* and *Cassia*). The little birds are very inconspicuous, skulking in the clumps of *Triodia*, but attract attention by their song, which is a high and soft squeak: "tzee . . . tzee . . . tzee . . .", continuously uttered. Now and then a male would perch on top of a *Triodia*-clump to deliver his song from this comparatively exposed position. This song certainly accounts for the fact that only males were collected, the female which is presumably silent would be much more difficult to trace.

Discussion. The emu-wrens were revised by Keast (1957a) with whose conclusion that *Stipiturus ruficeps* should retain specific status I fully agree.

***Malurus lamberti mastersi* Mathews**

Purple-backed Wren

Malurus lamberti mastersi Mathews, Novit. Zool. 18, 1912, p. 360—Northern Territory (Alexandra).

Six specimens (Table XLVI).

Irides dark brown, bill male black, female terracotta, legs grey.

Common in dense scrub, where usually seen in pairs or small parties.

Discussion. Not having seen enough material of the various races to form an independent opinion I follow Mack (1934) in assigning these specimens to *mastersi*. The Western Australian Museum has also two males from Bernier Island, three from Dorre Island, and several from Dirk Hartog Island. The Bernier Island specimens belong to the well-marked race *bernieri*, whereas those from Dirk Hartog agree fully with the mainland race. The three skins from Dorre Island show some variation, one is close to *bernieri*, another agrees almost entirely with *mastersi*; probably Dorre Island is inhabited by a variable intermediate population.*

The museum also has seven males of *dulcis* from the Northern Territory and the Kimberley Division, whence we have specimens from Syroth River, Ord River, and Wotjulum. One of the Ord River specimens has the crown and ear coverts very blue, and may belong to *mastersi*, but about the Wotjulum specimen there can be no doubt, it perfectly agrees with a skin from South Alligator River, the type locality of *dulcis*. It thus considerably extends the range as given by Mack. Whittell & Serventy (1948) list *M. dulcis* under the name of *M. amabilis*, but in view of Mack's (1934) remarks it seems better to keep the two separate. I find it difficult to believe that *dulcis* is specifically different from *lamberti*, but having no females I am not in a position to judge how much these differ from females of *lamberti*, and all these forms belong to a notoriously difficult group on which the last word has not yet been said or written.

I take the liberty to add a few words about *Malurus splendens*. Mack (1934) condemned his own new subspecies *aridus* to a synonym of *riordani* Mathews, described from Yalgoo, when he wrote that the single specimen from Yalgoo he examined agreed with *aridus*, and subsequently it was listed as such by Whittell & Serventy (1948). In the collection of the Western Australian Museum are one male from Yalgoo and one from Mt. Magnet, both in fresh plumage. These specimens do not differ from males from Perth and Albany (type locality of *splendens*) and other localities in the south-west. Therefore *riordani* is evidently a synonym of *splendens*. Whether or not *aridus* is a separable race I am unable to say as no specimens from its type locality or from other localities in the eastern part of the range of the species are available to me.

***Malurus leucopterus leuconotus* Gould**

Blue-and-White Wren.

Malurus leuconotus Gould, Proc. Zool. Soc. Lond. 1865 (June), p. 198—Interior of Australia, precise locality unknown.

Four specimens (Table XLVII).

* During a recent collecting trip to Dorre and Bernier Islands (July 1959) this supposition was confirmed. The results of this trip will be published separately.

Male, irides dark brown, bill black, legs grey; female irides sepia, bill pale pinkish brown, base of manible almost white, legs pinkish grey.

Not uncommon in dispersed *Acacia* and *Cassia* scrub in open country, where found in pairs or small parties.

Discussion. There is no difference between specimens from various parts of continental Australia; perhaps specimens from the south-eastern part of the range average slightly larger, but the difference is negligible. Even Mathews (1917b) had observed that *leuconotus* and *cyanotus* are scarcely separable, and Mack (1934) united all Australian populations under one name. I refer to Mack's paper for synonymy. Contrary to Mack, I apply a trinomial since there is no doubt in my mind that *leuconotus* is conspecific with the insular *leucopterus*.

***Epthianura tricolor* Gould**

Crimson Chat

Epthianura tricolor Gould, Proc. Zool. Soc. Lond. 8, (1840), July 1841, p. 159—Habitat unknown.

Six specimens (Table XLVIII).

Irides white, bill black, legs dark grey. All specimens are in rather fresh plumage, none shows moult. Gonads enlarged.

At Tambrey, this species was common on a place where spinifex had been burned one or two years previously, and where an open vegetation of Leguminosae, Solanaceae, etc. predominated. The birds were in full song and showed pair formation, and were evidently going to breed.

Discussion. As Keast (1958c) has shown, this nomadic species shows no geographical variation.

***Petroica cucullata* (Latham)**

Hooded Robin

Muscicapa cucullata Latham, Index Ornith, Suppl. 2, 1801, p. li—New South Wales (reference copied).

Melanodryas picata Gould, Handb. Birds Aust. I, 1865, p. 285—North-west coast of Australia (reference copied).

Six specimens (Table XLIX).

Irides brown (♂) or sepia (♀), bill and legs black. No moult, plumage somewhat abraded, No. A 8141 strongly abraded.

A fairly common species in half open country, seen solitary or in pairs.

The species has been revised by White (1937) and by Keast (1958a), and for comparison I give here the measurements of all specimens in our collection.

Western Australia (North-West):

♂: 91, 93, 94, 94, 95, 95, 95, 97½.

♀: 87, 88, 89, 89.

Western Australia (Day Dawn, Mid-West):

♂: 92, 97.

♀: 86, 87, 88, 90.

Western Australia (South-West):

♂: 92, 94, 95, 95, 97, 98.

♀: 85, 86.

Western Australia (Well 37, Canning Stock Route):

♂: 89.

Northern Territory (Eureka, S. Alligator River):

♂: 88, 89.

South Australia:

♂: 97½.

New South Wales:

♂: 102.

♀: 93, 93, 95.

Victoria:

♂: 100.

From this scanty material it would seem possible to recognise three size races: a large race from New South Wales and Victoria, an intermediate one from Western Australia (except interior and north), and a small one from the Northern Territory and adjacent parts of Western Australia. However, White's and Keast's figures show that there is in the Kimberley Division and the Northern Territory a greater range of variation (87-94), which means that these birds are not satisfactorily separable from those of the south-west of Western Australia. Keast writes of a gradient of diminishing size from south to north, but this apparently also exists going from east to west. Personally—this indeed is purely a matter of personal opinion—I consider it, contrary to Keast, inadvisable to nomenclatorially recognise the smaller northern populations (*picata*) because this would involve that all the specimens from Western and South Australia, half the continent, would have to be indicated by the awkward *cucullata-picata*. In this connection it is instructive to note that, though both White and Keast recognise two size races, *cucullata* and *picata*, the first-mentioned author includes all Western Australia in *picata*, whereas the second unites the birds from the south-west of the state with the nominate race. It is curious that Keast omits all reference to White's paper, which was apparently unknown to him.

The specimens from West Pilbara are interesting from the zoogeographic point of view as they agree in measurements with those from the south-west, and are not smaller. Just as with *Rhipidura leucophrys* the size-gradient apparently begins in the arid areas to the north and east of the district.

***Rhipidura fuliginosa preissi* Cabanis**

Grey Fantail

Rhipidura Preissi Cabanis, Museum Heineanum I, 1850-51, p. 57—West Australien.

Two specimens (Table L).

Irides reddish brown, bill brown, legs black. Apparently no moult, plumage somewhat abraded. The difference in tail-length between the two specimens is remarkable.

This species was not common, it occurred in the forest along the Fortescue River and also in dense secondary growth some distance away from the river. As elsewhere, the birds were very confiding.

Discussion. Recently the species has been revised by Keast (1958a) according to whom the area of Carnarvon and the Fortescue River is inhabited by an unnamed population that is close to, but not identical with, *subphasiana* Mathews of the Kimberley Division, and distinct from *preissi*.

Contrary to Keast, I find the two specimens from the Fortescue identical with true *preissi*; also I fail to find much variation in size in different parts of the state, as the following figures show. At any rate, specimens from the Hamersley region agree in size with those of the south-west, and I have not the slightest hesitation in referring them to *preissi*. Our New South Wales specimens, which according to Keast should bear the name *alisteri* Mathews,

differ from *preissi* by having a darker, blackish, crown, darker throat spot, and darker buffish under surface.

Measurements of specimens in our collection are:

South-western Australia (Rabbit Island, Garden Island, Harvey River, Moir Pass, Herdsman Lake, Ellenbrook, Denmark District):

♂: 71, 76, 77, 77, 77; ♀: 72, sex ? : 73, 73.

Kimberley Division (Ord River, ♀: Point Torment, sex ?):

♂: 75; sex ? : 64½.

New South Wales:

♂: 75, 78, 79; ♀: 71; sex ? : 70.

I cannot refrain from commenting on Keast's (1958a) figure 1, which gives a not entirely correct picture as far as the north-west is concerned. Firstly, *Rhipidura fuliginosa* is not strictly a mangrove species in this area, but occurs in any well-wooded country away from the coast. Secondly the mangroves in the region do not form a continuous belt from the Kimberley Division south to Point Cloates, as suggested in the figure, but there is a gap of some sixty miles along the Eighty Mile Beach. Moreover I very much doubt if the distributional gap indicated by Keast south of Shark's Bay really exists, it seems much more likely that the species has an uninterrupted range from the south-west to the Fortescue River, but at present I have no material to prove this assumption. I must draw attention to the fact that Keast examined specimens from Carnarvon, though the place occupies a blank on this map.

It will be appreciated that the identity of the Fortescue River birds with *preissi* somewhat affects Keast's hypothesis on correlation between colour and humidity.

Condon (1951b) united all birds from the southern and eastern parts of Australia with the western ones under one name (*preissi*) but in view of the findings of Keast and myself this would seem to go too far.

Rhipidura leucophrys leucophrys (Latham)

Willie Wagtail

Turdus leucophrys Latham, Index Ornith. Suppl., p. xlv, 1801—New South Wales (Sydney) (reference copied).

Muscicapa tricolor Vieillot, Nouv. Dict. d'Hist. Nat., nouv. éd., XXI, 1818, p. 490—Timor — New South Wales (reference copied).

Rhipidura motacilloides Vigors & Horsfield, Trans. Linn. Soc. Lond. 15, 1827, p. 248—George's River, New South Wales.

Leucocirca laticauda Swainson, Nat. Lihr. (Jardine) XIII, 1832, p. 130, pl. XI—Australia or the East Indies, designated type locality Sydney, New South Wales (Mathews, 1923b).

Rhipidura picata Gould, Introd. Birds Aust., 1843, p. XXXIX—Port Essington.

Rhipidura tricolor utingu Mathews, Aust. Avian Rec. 1, 1912, p. 90—Cape York.

Leucocirca leucophrys carteri Mathews, Birds Aust. IX, 1921, p. 41—Broome Hill, South-west Australia.

Five specimens (Table LI).

Irides dark brown, bill and legs black. None of the specimens shows moult.

A common bird, as everywhere else in its range. Normally seen in pairs.

Discussion. Keast (1958a, p. 85) claimed the existence of a size gradient going from south to north, but his material from the north-west was very poor and in the measurements of his two specimens from Point Cloates evidently a

misprint occurs, which renders them useless. The present series shows that there is no difference in size between birds from West Pilbara and birds from the south-west, for which Keast measured wing-lengths of 92-101, average 98 mm in 8 specimens. I have not remeasured the specimens from the south-west in our museum's collection, as Dr. Keast already used them for his study.

Keast (1958a) and Mack (1953) recognised two subspecies, a large southern and a small northern one, but on the basis of Keast's own figures, I do not consider it justified to maintain the northern populations as a distinct race. It would be nonsense to call the populations of the south-west (wing 92-101, cf. Keast l.c.) *leucophrys* and the smallest ones of Cape York (wing 91-96) and coastal Northern Territory (wing 91-96) *picata*. It may be remarked, moreover, that Junge (1939) found for four birds of Cape York wing measurements of 92-101 mm. Though the existence of a difference in average size is beyond doubt, the range of overlap is such that it should not be used as an excuse for nomenclatorial splitting.

In recent years several partial revisions of the species have appeared; Keast revised the Australian populations, whereas Mayr (1931), and Junge (1939) commented on the populations of the islands to the north, concluding that the whole area from the Moluccan Islands to the Bismarck Archipelago is occupied by one single subspecies of somewhat variable dimensions, which has to be called *Rhipidura leucophrys melaleuca* (Quoy & Gaimard).

Hartert (1905) initially stated that the difference between *leucophrys* and *melaleuca* is one of bill-size, the latter subspecies having a much larger bill. Curiously Stresemann (1914) and Hartert (1930) later did not mention this character at all and Hartert commented: "It was not so stupid of us and Ogilvie-Grant to unite all the birds from East and North Australia with those of New Guinea and Papuan Islands. The various forms seem to differ only by size" His comments may have influenced Mayr (1931), who wrote in his discussion of *melaleuca*: "It may be noted, however, that the specimens from South New Guinea and Aru Island are, on the average, slightly smaller and approach somewhat the smaller *picata* Gould of Northwest Australia". Later Mayr (1941b) included *picata* in his List of New Guinea Birds as probably occurring near Merauke.*

In order to ascertain the position of the south New Guinea birds, and to check on the validity of *melaleuca* as opposed to the nominate race, I examined 18 specimens of *melaleuca* from several Moluccan Islands, the Aru Islands and many parts of Dutch New Guinea, from the Leiden Museum, kindly sent on loan by Dr. Junge. There is no material from Merauke among them, but there are specimens from Bivakeiland, Alkmaar, and the Aroe Islands. All

* The name *picata* was first used for birds from southern New Guinea by Stresemann & Paludan (1935); these authors do not mention the size of the bill, and the yellowish tinge of the under surface regarded by them as diagnostic of *picata* is probably due to stain of some sort, it certainly does not occur normally in birds from Northern Australia.

these specimens agree in their large bill-size, in which they differ conspicuously from all Australian specimens, and in this material there are no signs that the birds of the Aroe Islands or South New Guinea approach the nominate race.

To conclude: the species *Rhipidura leucophrys* can be divided into two clear-cut races: the small-billed *leucophrys* which occupies the whole of the Australian continent, and the large-billed *melaleuca* which occupies the Moluccas, New Guinea and satellite islands, Bismarck Archipelago and the Solomon Islands. New Guinea is inhabited by one race only, and the race *picata* (which anyway must be considered a synonym of *leucophrys*) must be removed from the New Guinea list.

Both subspecies show a considerable but irregular geographic variation in size (of wing), but this is not enough to base additional subspecies on. Intergradation between *leucophrys* and *melaleuca* is not known to occur.

***Pachycephala rufiventris rufiventris* (Latham)**
Rufous Thickhead

Sylvia rufiventris Latham, Index Ornith., Suppl., 1801, p. xli—New South Wales (reference copied).

Five specimens (Table LII).

Irides male chestnut brown, female dark brown, bill and legs black or blackish grey. Weight of no. A 8097, 18 g., of A 8098, 20 g. The nos. A 8094 and A 8095 are in somewhat abraded plumage, the other specimens in fairly fresh plumage, none shows moult.

A common species in woodland along river beds and near water holes.

Discussion. These specimens are identical with material from the south-west, and the males with males from New South Wales, though they are perhaps on the average a trifle paler on the under surface. From the south-west I have several specimens which are quite as dark underneath as skins from New South Wales, hence I agree with Mayr (1954) that all these populations belong to the nominate race.

***Colluricincla harmonica rufiventris* Gould**
Shrike -Thrush

Colluricincla rufiventris Gould, Proc. Zool. Soc. Lond. 8, (1840), 1841, p. 164—Swan River, Western Australia.

Colluricincla rufiventris murchisoni Mathews, Aust. Avian Rec. 1, 1912, p. 94—East Murchison, Westralia.

Colluricincla rufiventris carteri Mathews, Aust. Avian Rec. 5, 1923, p. 35—Near Albany, South-west Australia.

Five specimens (Table LIII).

♂: irides red-brown, bill and legs horny black; ♀: irides brown, bill maxilla black, tomium and mandible fleshy bluish white, legs bluish grey.

Fairly common along creek-beds and in other well-wooded places throughout the area.

Discussion: This material, with two specimens from North-West Cape in our collection, differs from southern specimens by having the rufous of the under surface more extended, and the grey of the breast reduced. The females have the whole under surface buffish, the males are buff from the lower breast downwards. It may be remarked that the characters (more rufous on

under surface, brownish bill) ascribed by Serventy & Whittell (1951) to juvenile birds, actually are the female characters. Females also have more or less distinct longitudinal striae on the upper breast.

Originally I believed that the differences listed above might suffice for subspecific separation of the northern birds, but in view of the fairly large amount of individual variation in the presence of buff coloration in the southern birds, I prefer to keep all these populations under one name. Of Mathews's *murchisoni* the American Museum of Natural History (Mathews collection) has only two specimens, of which I have received the best one on loan; it is dark grey on the breast, and agrees with the southern birds, hence the name *murchisoni* cannot be used for the northern birds by those who may consider the slight difference worthy of nomenclatorial recognition, and remains in all circumstances a synonym of *rufiventris*.

Going from Perth to the south there may be a slight darkening of the grey colour, but if such a trend really exists it is much too slight to justify recognition of *carteri* (I have compared good series, including topotypes of both *rufiventris* and *carteri*). Mathews (1931) had relegated both *murchisoni* and *carteri* to synonymy.

***Oreoica gutturalis gutturalis* (Vigors & Horsfield)**
Bell-Bird

[*Falcunculus*] *gutturalis* Vigors & Horsfield, Trans. Linn. Soc. Lond. 15, (1826), 1827, p. 212—Kent's Group (errore!) = Sydney (designated by Mathews).

Oreoica cristata westralensis Mathews, Novit. Zool. 18, 1912, p. 377—South-West Australia.

Three specimens (Table LIV).

Irides of male orange-yellow, bill black, legs dark grey. No. 8368 was shot while singing, testes large, plumage abraded, subcutaneous parasites were found on head and neck. None of the specimens shows moult.

Judging from the song, the species was not uncommon near Tambrey but the birds were shy and difficult to collect.

Discussion. There is no difference either in coloration or in measurements between birds from the north-west, south-west, and south of Western Australia (material compared from Albany, Williams, Ravensthorpe, Lake Dundas). Three specimens from the Canning Stock Route are paler, browner, on the dorsal surface, but then specimens in abraded plumage (as they are) are always lighter so that I do not attach much significance to this difference.

Mathews (1912a) described *westralensis* as differing from the nominate race: "... in its slightly larger size, lighter and greyer coloration above and below", but our material does not show these differences.

Some additional wing measurements are:

South-West Australia (Albany, Ravensthorpe, Ten-terden):

♂: 107½, 110.

♀: 99.

Canning Stock Route (Wells 16 and 24):

♂: 107, 110, 110.

New South Wales (Australian Museum):

♂: 106, 107.

♀: 106, 108.

The New South Wales material was insufficient for evaluating possible very slight differences in tone or colour, but in view of the strong individual variation (largely caused by wear), I see no reason to maintain *westralensis* and am therefore in full support of Mayr's (1953) views. Condon (1951b, p. 41) had already reduced *clelandi* Mathews from Coonalpyn, South Australia, to a synonym of the nominate race.

Having no material from the Kimberley Division (*mungi* Mathews 1912), Northern Territory (*pallidus* Mathews 1912), and Dirk Hartog Island (*lloydi* Carter & Mathews 1917), to assist me in forming an independent opinion, I maintain a trinomial on the authority of Mayr (1953).

Mathews's designation of Sydney as type locality of the species is unfortunate as, at least normally, it does not occur there (Hindwood 1942).

***Climacteris melanura wellsi* Ogilvie-Grant**

Black-tailed Tree-Creeper

Climacteris wellsi Ogilvie-Grant, Ibis (9) 3, 1909, p. 664—Clifton Downs, Upper Gascoyne River.

Whitlocka wellsi striata Mathews, Bull. Brit. Orn. Cl. 44, 1923, p. 15—Shaw River, Mid-west Australia (reference copied).

Six specimens (Table LV).

Irides brown, bill black, white at gape, legs black. The specimens are in slightly abraded plumage, no moult. Specimen A 8099 has the black throat of a male and may have been incorrectly sexed as a female.

Not uncommon at Tambrey Station, where occurring in the widely spaced gumtrees of fairly open parklike country. The song is a whistling note, repeated from six to eight times: "tseet—tseet—tseet— . . ."

Discussion. A well marked subspecies, much more rufous all over than the nominate race occurring in the Kimberley Division.

I am convinced that the closest ally of *Climacteris* is *Neositta*, and that these genera have nothing to do with *Certhia* or *Sitta*.

***Dicaeum hirundinaceum* (Shaw)**

Mistletoe Bird

This widely distributed species was during our visit extremely rare in the area. On 12th July I observed several specimens on Marillana Station, and Mr. Buller thinks he saw one female flying overhead on Millstream Station.

***Pardalotus substriatus murchisoni* Mathews**

Striated Pardalote

Pardalotus striatus murchisoni Mathews, Novit. Zool. 18, 1912, p. 388—West Australia (Murchison).

Five specimens (Table LVI).

Male, irides brown, bill and legs black; immature female, irides grey-brown, bill black, white at gape, legs black. No. A 8236 has the crown feathered green-yellow, not black, and is therefore probably immature. None of the specimens shows moult.

Common and widely distributed in the area.

Discussion. Not having enough material to form an independent opinion I follow Hindwood and Mayr (1946) in recognising the race

murchisoni, though I note that Condon (1951b, p. 58) calls it an extremely doubtful form.

***Pardalotus rubricatus pallidus* A. J. Campbell**

Red-browed Pardalote

Pardalotus pallida A. J. Campbell, Emu 8, 1909, p. 142—The region of the Coongan and De Grey Rivers.

Two specimens (Table LVII)

Irides yellow, maxilla horny black, mandible bluish white, legs grey-flesh. No moult, plumage somewhat abraded.

Apparently less common than the preceding species.

Discussion. The Western Australian Museum has material from the north-western part of the state only, so that comparison with representatives of other named populations is impossible. The description of *pallidus*, however, is convincing and the race has been accepted by Condon (1951b).

***Melithreptus laetior* Gould**

Golden-backed Honeyeater

Melithreptus laetior Gould, Ann. Mag. Nat. Hist. (4) 16, 1875, p. 287—Lake Eyre.

Melithreptus gularis coongani Mathews, Novit. Zool. 18, 1912, p. 392—North-West Australia (Coongan River).

Five specimens (Table LVIII).

Irides brown, bare skin round eye lemon yellow, bill black, legs orange. None of the specimens is in moult, their plumage is slightly abraded except no. A 8111 which is strongly abraded.

A moderately common inhabitant of the wooded areas.

In default of topotypical material I am not able to judge the validity of the described races, but I do not expect them to be valid as their descriptions are far from convincing. Though Condon (1951b) certainly has a strong case in reducing *laetior* to subspecific status, I prefer to keep *gularis* and *laetior* as different species. The morphological differences between *gularis* and *laetior* are of about the same magnitude as those between *M. lunatus* and *M. albogularis*, which at a time, have been considered to belong to one species, but their specific diversity has now been well established, most recently by Hindwood (1951) and Mack (1953).

***Lichmera indistincta indistincta* (Vigors & Horsfield)**

Brown Honeyeater

[*Meliphaga*] *Indistincta* Vigors & Horsfield, Trans. Linn. Soc. Lond. 15, 1827, p. 315—King George's Sound, on the south coast of New Holland.

Glyciphila? ocularis Gould, Synops. Birds Aust. pt. IV, 1838, descr. p. 6—Van Diemen's Land (error) = New South Wales.

Glyciphila? subocularis Gould, Synops. Birds Aust. pt. IV, 1838, descr. p. 6—New South Wales.

Stigmatops indistincta rufescens Mathews, Novit. Zool. 18, 1912 (January), p. 402—Northern Territory (Crawford Springs).

Stigmatops indistincta media Mathews, Novit. Zool. 18, 1912 (January), p. 403—Parry's Creek, North-West Australia.

Stigmatops indistincta perplexa Mathews, Novit. Zool. 18, 1912 (January), p. 403—Marble Bar, North-West Australia.

Stigmatops indistincta mclvillensis Mathews, Aust. Avian Rec. 1, 1912 (2 April), p. 50—Melville Island, Northern Territory.

Stigmatops indistincta ouida Mathews, Aust. Avian Rec. 1, 1912 (18 September), p. 98—Cairns, North Queensland.

Lichmera indistincta yorki Mathews, Aust. Avian Rec. 5, 1923 (21 February), p. 37—York, West Australia.

Lichmera indistincta perthi Mathews, Aust. Avian Rec. 5, 1923 (21 February), p. 37—Perth, West Australia.

Lichmera indistincta milligani Mathews, Aust. Avian Rec. 5, 1923 (21 February), p. 37—Stirling Ranges, South-west Australia.

Seven specimens as listed (Table LX).

Irides brown-grey, bill black, legs dark grey. No. A 8209 is moulting rectrices, no. A 8212 shows moult in the wings. It is likely that specimen no. A 8212 has been incorrectly sexed as a male, for its measurements point to its being a female.

A common species wherever there were trees. The attractive song is curiously reminiscent of that of *Acrocephalus* sp., a fact already noted by Le Souëf (1900, p. 198) and Serventy & Whittell (1951).

Discussion. Stresemann (1912) undertook the only serious revision ever made of the species. On the Australian continent he recognised two races: the nominate race in the west and north, and *ocularis* in the south-east. As differential character he mentioned only in adult males the somewhat darker upper surface, particularly the darker crown, of *ocularis* as compared with *indistincta*. The races *rufescens*, *media* and *perplexa* he referred to the synonymy. He tentatively recognised *melvillensis* Mathews, but apparently only for the zoogeographic reason that Melville Island birds seemed to agree fully with *ocularis* and not with *indistincta*, to which he assigned the birds of the opposite mainland of the Northern Territory.

Subsequently Mathews, ignoring Stresemann's work, described four more races, of which he himself later (Mathews 1931) relegated two to synonymy.

I have compared large series from Western Australia and the Northern Territory with two skins from New South Wales and five from southern Queensland, and found that even Stresemann's division into two races cannot be upheld. Though the material from Queensland and New South Wales was scanty, it contained some adult males. It proved quite impossible to distinguish these from specimens from south-western Australia. Therefore I consider all Australia to be inhabited by one race only (I have seen topotypical material of all races, except *oida* and *melvillensis*).

The range of the nominate race apparently includes southern New Guinea, whereas the races *limbata* and *nupta* are found on the Lesser Soenda Islands and the Aroe Islands respectively.

The genus *Gliciphila* as understood by recent authors (for example Whittell & Serventy 1948, and Serventy & Whittell 1951) is clearly artificial. The Brown Honeyeater is certainly not congeneric with the type of *Gliciphila*, which is *G. melanops*, and until its relationships are better understood it seems best to retain the species in *Lichmera*. The third species included in the genus by Serventy & Whittell (*albifrons*) apparently belongs to the genus *Meliornis* and should be known as *Meliornis albifrons*.

Certhionyx variegatus Lesson

Pied Honeyeater

On 23 July I observed a pair in some bushes in the middle of open country on Millstream Station.

Meliphaga virescens forresti (Ingram)

Singing Honeyeater

Ptilotis forresti Ingram, Bull. Brit. Orn. Cl. 16, 1906, p. 116—Alexandra, Northern Territory (reference copied).

Ptilotis sonora murchisoni Mathews, Novit. Zool. 18, 1912, p. 405—West Australia (East Murchison).

Ptilotis sonora rogersi Mathews, Novit. Zool. 18, 1912, p. 406—North-West Australia (Wyndham).

Ptilotis sonora decipiens Mathews, Novit. Zool. 18, 1912, p. 406—North-West Australia (Mungi).

Meliphaga v *[irescens]* *lipferti* Mathews, J. Roy. Soc. W. Aust. 27, 1942, p. 77—Well 33 on the Canning Stock Route.

Meliphaga v *[irescens]* *lewisi* Mathews, J. Roy. Soc. W. Aust. 27, 1942, p. 77—Lewis Island, Dampier Archipelago.

Seven specimens as listed (Table LX)

As Whittell & Serventy (1948, p. 94 footnote 1) pointed out this species is in need of revision. The presence in the Western Australian Museum of a good series, and of the type specimens of four described forms enabled me to bring some order into the chaos created by Mathews. Actually the geographic variation follows a fairly simple pattern; birds from the south-west are large and dark, birds from the north and interior are smaller and paler, especially on the under surface. However, to express this variation in ternary nomenclature is not so simple, for *Meliphaga virescens* is a common species with a continuous range throughout the Australian Continent and the variation that occurs is extremely gradual. On the other hand the differences between some of the extremes are such, that I consider it undesirable to keep all populations under one name.

Before describing the geographic variation in detail something has to be said about the type locality of the species. Mathews (1914, p. 101) suggested as type locality Shark's Bay, and Stresemann (1951) thought that perhaps the type came from Bernier Island. The type specimen of *Melithreptus virescens* Vieillot is still present in the Paris Museum, where Dr. Jouanin kindly compared it with seventeen specimens from various localities which I sent him on loan. He also supplied me with some information concerning its provenance. The locality is given as "Nouvelle-Hollande" and under the socle of this old mounted bird are some manuscript lines written by Dufresne, who was "aide-naturaliste au Muséum" from 1793 to 1832: "Asie australe. Corvette le Naturaliste. Expédition du Capitaine Baudin. An 11". This inscription proves (writes Dr. Jouanin) that the specimen was part of the collection brought back to France in 1803 by the Capitaine Hamelin whom Baudin sent back at the end of 1802 with all the collections already gathered by the expedition. But this historical detail is without great meaning in the present case.

The type is large (wing 95-96 mm, tail 88, tarsus 25, bill damaged, but not small), and Dr. Jouanin thinks that the type locality may be safely restricted to Bernier Island.

It is curious—but not really surprising from a careless author as Mathews, who was certainly responsible for these notes—that Carter & Mathews (1917) stated that: “The type of the Singing Honey-eater was obtained at Shark’s Bay by the French expedition of 1818 . . .”, an error they repeated four years later (Carter & Mathews 1921). This notwithstanding the fact that the species had already been described in 1817!

As regards the geographic variation in Western Australia, the largest and darkest birds occur on Rottnest Island; our series from there shows uniformly large measurements, including a large bill, and very dark under parts. This would seem to indicate the validity of *insularis*, but unfortunately many birds from the mainland of the south-west (and not only from the coastal area) are just as large and as dark, though others are smaller and paler on the under surface.

Two specimens from North Twin Peak Island are as large and dark as the Rottnest specimens but differ by having appreciably shorter bills. More material from this and from other islands off the south coast is needed before the characters of these populations can be fully understood.

In the south-west, as already stated, some birds are as large and as dark as those from Rottnest, and in general terms the populations from this area may be described as fairly large and rather dark underneath. The length of the bill is variable. Specimens from South Australia (*sonora*), Eucla, and Ebano (*glauerti*) are identical.

The birds from Dirk Hartog Island, Dorre Island and Bernier Island, and surprisingly even those from North-West Cape, are as large as the southern birds, and have large bills, but are slightly paler on the under surface.

Specimens from Carnarvon, on the other hand, are somewhat smaller and have definitely smaller bills (only three specimens are available). It seems therefore that in the mid-west the large populations are purely coastal.

Smaller specimens with pale under surface occur in the north-west, and specimens from East Murchison (*murchisoni*), and Barrow Island are identical. The only specimen from Lewis Island (*lewisi*) is rather large, but does not show other differences and it is unlikely that *lewisi* is a valid race.

In nomenclature, I think that the geographic variation can best be expressed by recognising two races in Western Australia.

1. *Meliphaga virescens forresti* (Ingram), with the synonyms listed on a previous page.

Distribution. Northern and inland Australia, in Western Australia at least as far south as the Hamersley region and East Murchison; also Barrow Island and Lewis Island. Birds from Carnarvon are intermediate between this and the nominate race.

The material I have seen from the Northern Territory and from near Alexandra (type locality of *forresti*) was old and not in good condition, but in view of Condon’s (1951b, p. 60) remarks it

seems safe to apply the name *forresti* to the birds from Western Australia.

2. *Meliphaga virescens virescens* (Vieillot).

Melithreptus virescens Vieillot, Nouv. Dict. d’Hist. Nat., Nouv. éd. XIV, 817, p. 329—la Nouvelle Hollande, restricted to Shark’s Bay by Mathews (1914), and here further restricted to Bernier Island.

Ptilotis sonorus Gould, Proc. Zool. Soc. Lond. 8, (1840), 1841, p. 160—South and Western Australia, restricted to South Australia by Mathews (1912a).

Ptilotis insularis Milligan, Emu 11, 1911, p. 124—Rottnest Island, off Fremantle, Western Australia.

Ptilotis sonora broomei Mathews, Novit. Zool. 18, 1912, p. 405—Broome Hill, South-West Australia.

Meliphaga virescens hartogi Mathews, Bull. Brit. Orn. Cl. 40, 1920, p. 76—Dirk Hartog Island, West Australia (reference copied).

Meliphaga virescens glauerti Mathews, J. Roy. Soc. W. Aust. 27, (1940-1941), 1942, p. 77—Ebano.

Distribution. South-western Australia and southern South Australia, in coastal Western Australia north to North-West Cape.

Birds from the northern part of the range (including Bernier Island, the type locality) are paler underneath than those from the south, but the difference is too slight to be recognised in nomenclature.

The measurements of all the material from Western Australia in the Western Australian Museum, except juveniles and specimens which show heavy moult, are listed below. It is likely that a number of specimens are incorrectly sexed, which may explain the great size differences in specimens from the same localities and allegedly of the same sex. I feel justified in doubting much of the sexing since in the specimens recently collected on Bernier and Dorre Islands, at Carnarvon, and at North-West Cape, and sexed by me personally, a difference in size between the sexes is evident (Table LX).

Meliphaga keartlandi (North)

Grey-headed Honeyeater

Ptilotis keartlandi North, Ibis (7) 1, 1895, p. 340—McMinn’s Range, Central Australia.

Twelve specimens (Table LXI).

Irides grey-brown, bill black, legs fleshy grey. Nos. A 8312 and A 8318 are fledglings. No. A 8313 is moulting rectrices, the other specimens are not in moult, they are in slightly to strongly abraded plumage.

This species was plentiful in a somewhat specialized habitat: low trees and scrub in rocky gullies and other rocky environments; never observed in flat country. Apart from the two fledglings collected I have on several occasions seen young birds attended to by their parents.

Discussion. I have no material for comparison from outside Western Australia, but in view of Condon’s (1951b, p. 61) remarks it seems best to give the species a binomial.

Meliphaga penicillata carteri (A. J. Campbell)

White-plumed Honeyeater

Ptilotis carteri A. J. Campbell, Vict. Nat. 16, 1899 (4 May), p. 3—no locality given, but apparently Point Cloates.

Ptilotis penicillata ladasi Mathews, Novit. Zool. 18, 1912, p. 413—West Australia (East Murchison).

Ptilotis geraldtonensis Ashby, Emu 20, 1921, p. 190—Geraldton and Dongara, Western Australia.

Five specimens (Table LXII).

The specimens are in somewhat abraded plumage, and show no moult. No. A 8168 is perhaps juvenile, which may explain its small measurements.

Very common in the gum trees along rivers and creeks.

Discussion. Mathews (1931) placed *ladasi* and *geraldtonensis* in the synonymy, and I fully agree with him. Unfortunately material from the Kimberley Division (described as *calconi* Mathews) is not available to me, so that I cannot judge the validity of that race. *M. p. carteri* is very different from the nominate race: slightly smaller, upper parts paler and more yellowish brown, not grey, sides of head and throat canary yellow instead of head greenish yellow and throat greyish, under surface light yellowish instead of brownish grey with medially only a trace of yellow.

The description of *leilavalensis* North (1899), published two weeks earlier than that of *carteri*, seems to indicate a form close to *carteri*, and I have been unable to examine material of the former. Dr. Keast (oral communication) has assured me, however, that *leilavalensis* and *carteri* are different.

In the material from the Western Australian Museum no size gradient within the state is apparent, specimens from the southern part of the range of the race measure:

Ebano: ♀: 76.

Yandanooka: ♂: 81, 81, 81, 81, 82.

Moora: ♂: 78 (abraded).

In contrast the measurements of some specimens from New South Wales are: ♂: 85, 85, 85, 87, 88, 91.

Myzantha flavigula lutea Gould

Mynah

Myzantha lutea Gould, Proc. Zool. Soc. Lond. 7, (1839), 1840, p. 144—North-west coast of Australia (Derby (restricted by Mathews)).*

Myzantha flavigula wayensis Mathews, Novit. Zool. 18, 1912, p. 418—West Australia (Lake Way).

Four specimens (Table LXIII).

Irides sepia, bill orange-yellow, basal third of bill and bare skin round eyes yellow, legs light orange or yellow-orange. No moult, plumage abraded.

A common species which, moreover, does not avoid the vicinity of man.

Unfortunately we have but one specimen from the Kimberley Division (Wotjulum, not far from Derby, the restricted type-locality of *lutea*), and it is apparently immature. However, it does not seem to differ from material from the West Pilbara District. Specimens from Milly Milly and Nannine are also identical, which makes it practically certain that *wayensis* (type locality Lake Way, east of Nannine) is invalid. When Mathews described *wayensis* he only compared it with the very different *obscura* but with his typical nonchalance omitted all mention of *lutea*.

* The Beagle was anchored for two weeks at Swan Point, the north-western headland of King Sound (Whittell 1954, p. 101), the type specimens may have been obtained there, see discussion on p. 112.

Emblema picta Gould

Painted Finch

Emblema picta Gould, Birds Aust. III, 1842, pl. 97—North-west coast of Australia.

Seven specimens (Table LXIV).

Irides white, maxilla black with waxed tip, mandible red with pale blue base, legs flesh colour. Specimen no. A 8183 is beginning its wing moult, the other specimens are not in moult, their plumage is somewhat abraded. The immature male has the red confined to the lores and round the eyes, the throat is black.

The habitat of this finch agrees with that of *Amytornis striatus whitei*, e.g. rocky outcrops in and at the edge of spinifex-country. In such places it is common, occurring in pairs or in small flocks of up to about twenty specimens. The birds are apparently not fond of getting wet: on a rainy day I flushed several parties from small caves where they had evidently been sheltering.

Discussion. No races are recognizable (Keast 1958e). I take this opportunity to point out that Keast in the paper just referred to apparently overlooked *Aegintha temporalis cardwelli* Mathews (1942) from Cardwell, Queensland. I mention the fact so that *cardwelli* may be interred alongside Mathews's other follies in the synonymy of *Estrilda temporalis*. According to Keast, birds from Cardwell are intermediate between the nominate race and *minor*.

Whittell & Serventy (1948, p. 99) and Keast (1958e) have united this species with others in the genus *Zonaeginthus*, but *Emblema* Gould 1842, of which *E. picta* is the type species, has nine years priority over *Zonaeginthus* Cabanis 1851, and must be used instead.

As Keast (1958e, p. 221, footnote) has pointed out, *Emblema* is not preoccupied by *Amblema* the facts being as follows: Iredale (1930) gave the generic name *Cayleya* to replace *Emblema*, an action he tried to justify as follows: "When Gould introduced . . . his generic name, he was unaware that there was any prior use, but it has long been known that Rafinesque had proposed *Amblema*. I noted that Deshayes, in 1840 (Dict. Univ. d'Hist. Nat. (Orbigny), Vol. I., p. 334) proposed *Emblema* as a better spelling than *Amblema* and this unfortunately invalidates Gould's name." I checked the reference (d'Orbigny 1849) and found that the name *Emblema* is mentioned not intentionally to replace *Amblema*, but only as a matter of literary interest: "AMBLÈME. *Amblema* (plutôt *Emblema* d'εμβλημα, grappe; ouvrage de divers morceaux)." The way this is put shows clearly enough that *Emblema* was not intended for use in zoological nomenclature, so that Iredale's argument is invalid.

Recently I have received Steiner's (1960) paper in which the Painted Finch is listed as *Emblema picta*, and the genus *Zonaeginthus* is retained for *oculatus* and *bellus*. Personally I agree with other Australian authors that these three species are congeneric. I cannot help commenting on some other points in the work of Steiner, who evidently follows an unusual system of nomenclature. How otherwise can it be explained that he recognises a tribus *Chloromuniae* and a genus *Chloromunia* Mathews 1923,

with as subgenera *Erythrura* Swainson 1837, *Trichroa* Reichenbach 1862, and four others that have priority over *Chloromunia*? *Chloromunia* Mathews (1923) was proposed as a new name for *Trichroa* Reichenbach, allegedly preoccupied by *Trichrous* Chevalot 1858, and therefore is a still-born synonym of *Trichroa*. Moreover Mathews (1931, p. 472) discovered that *Lobospingus* De Vis is another older name for his *Chloromunia*, being based on the same species.

Poëphila guttata castanotis (Gould)

Zebra Finch

Amadina castanotis Gould, Synops. Birds Aust. pt. I, 1837 (Jan.)—Interior of New South Wales.

Six specimens (Table LXV).

Common, particularly along creek beds and in other bushland surrounded by open country.

According to Keast (1958e) there is no geographical variation in Australia, and I follow him without comment. Lack of literature has prevented me from checking if Whittell & Scriventy (1948) are right in rejecting the name *guttata* as preoccupied, hence I maintain it for the moment.

Grallina cyanoleuca (Latham)

Peewee

Corvus cyanoleucus Latham, Index Orn., Suppl., 1801, p. xxv—Sydney, New South Wales (reference copied).

Two specimens (Table LXVI).

Irides greenish yellow, maxilla white with blackish nostrils and tip, mandible white, legs dark. Weights, A 8275, 60 g; A 8274, 87 g. No moult. A 8275 in somewhat worn plumage, A 8274 fairly fresh.

The difference in size between the two specimens is remarkable.

As has been pointed out by Amadon (1950); no races are recognizable.

Artamus leucorhynchus leucopygialis Gould

White-breasted Woodswallow

Artamus leucopygialis Gould, Birds Aust. II, pl. 33, 1842—South Australia and New South Wales.

Artamus leucorhynchus parvirostris Hartert, Novit. Zool. 6, 1899, p. 424—Cape York Peninsula.

Artamus leucorhynchus harterti Mathews, Novit. Zool. 18, 1912, p. 367—North-West Australia, restricted to Parry's Creek by Mathews (1924, p. 166).

Artamus leucorhynchus melvillensis Mathews, Aust. Avian Rec. 1, 1912, p. 45—Melville Island, Northern Territory.

Three specimens (Table LXVII).

Irides brown; bill pale blue, tip black; legs blue-grey to dark blue-grey; no moult, specimen A8139 in fresh plumage, the two others in slightly worn plumage.

Fairly common near Millstream Homestead, where it associated with *A. cinereus* from which species it seemed not to differ in its habits. I noticed that during rainy weather birds would perch much more often than with fine weather. The clustering of the perched birds is remarkable; usually they would associate in small groups of three or four in close contact.

Discussion. The Australian populations of the species were revised by Keast (1958d), who considered it possible to recognise a smaller northern

race, besides the southern *leucopygialis*. The wing measurements of additional specimens in our collection are:

| | |
|-------------------------------|------------------------------------|
| Lavendall Island .. | ♂: 133 |
| Hermite Island | ♀: 132, 133 |
| Barrow Island | ♂: 131, 136; ♀: 129, 138 sex?: 135 |
| Port Hedland | ♂: 132; ♀: juv.: 130 |
| Lewis R., N.W.A. .. | ♂: 132, 133, 134 |
| Fitzroy R. | ♂: 131; ♀: 127, 132 |
| South Alligator R., N.T. | ♂: 127, 129, 130 |

As Keast (l.c.) gives for the largest population of New South Wales a maximum of 138 mm, it is apparent that specimens of the north-west can be just as large. Admittedly I have not seen topotypical *parvirostris*, but Gyldenstolpe (1955, p. 293) records a specimen from Cardwell, north Queensland, with a wing of 137 mm. I conclude that though specimens from the Kimberley Division and the Northern Territory apparently average slightly smaller, no excuse exists for maintaining *parvirostris*, a conclusion also arrived at by Gyldenstolpe. Keast does not state to which of the two races recognised by him he reckons the New Guinea specimens to belong; he only writes that they "are similar to the Australian form".

Mayr & Rand (1937, p. 184-185) and Junge (1939, p. 2-3) concluded that the New Guinea birds are identical with those from Australia, and therefore called them *leucopygialis*, but recently the discussion of the validity of *papuensis* was re-opened by Gyldenstolpe (1955, p. 293-294) who thought that it could be maintained on the basis of colour characters: "by having the upper parts of the body markedly more grayish, less brownish. In addition, they have the colour of the chin and throat grayish without any brownish tinge as is the fact in those Australian skins which have been available".

From the Leiden Museum I received five fresh-looking skins from New Guinea on loan for comparison with our Australian material and I found that as regards coloration they are identical. There is a certain amount of individual variation in specimens from any one locality; particularly the colour of the throat may vary from dark grey to brownish grey. As regards the more brownish colour of the upper parts found in some birds, Gyldenstolpe himself had suggested that this might be due to foxing. Actually foxing apparently only slightly affects the skins but old specimens are slightly more brownish, and are less dark on the forehead, than fresh skins, and also their bills are paler, more greenish blue.

The measurements of the New Guinea specimens examined are:

| | | |
|-----------------------------------|-------------------------|---|
| Alkmaar | ♂: 129, ♀: 114, ? : 121 | (wings of ♀ and sex ? strongly abraded) |
| Etnabaai | ♂: 136 | |
| Pionterbivak, Mamberamo River, .. | ♂: 135 | |

For additional measurements I refer to Mayr & Rand (1937) and Junge (1939). Evidently the specimens from south New Guinea are small, they have also smallish bills and are apparently even smaller than Northern Territory birds (cf. Junge's measurements), but as Junge pointed out, the difference is too slight to warrant recognition. In my opinion the validity of the race *leucopygialis* itself requires confirmation, it is very close to the nominate race.

Artamus personatus (Gould)

Masked Woodswallow

Ocypterus personatus Gould, Proc. Zool. Soc. Lond. 8, (1840), 1841, p. 149—Southern and Western Australia.

Artamus gracilis Ingram, Bull. Brit. Orn. Cl. 16, 1906, p. 105—Alexandra, Northern Territory (reference copied).

One specimen (Table LXVIII).

Irides light brown, bill milky blue, legs grey, weight 35 g, no moult, plumage fresh, only tips of rectrices slightly abraded.

Apparently uncommon. I have not observed this species.

No geographic variation exists in the species (Keast 1958d). As Keast omitted mentioning the name *Artamus gracilis* Ingram, I list it here in the synonymy.

Artamus cinereus melanops Gould

Black-faced Woodswallow

Artamus melanops Gould, Proc. Zool. Soc. Lond. 1865, p. 198—St. Becket's Pool, lat. 28° 30', Central Australia.

Four specimens (Table LXIX).

Irides brown, bill pale bluish, tip black, legs dark grey. No moult, plumage slightly abraded. Narrow white edges to the black under tail coverts are present.

Common everywhere in half open country where they would gather in exposed places and every now and then soar out to catch insects on the wing. I did not see them perch as close together as *A. leucorhynchus*.

Keast (1958d) recognised, besides some forms in Queensland which do not concern us, a large southern race (*tregellasi*) and a small northern one (*melanops*).

The measurements of specimens in the Western Australian Museum, from north-east to south are:

| | |
|----------------------------|----------------------------|
| S. Alligator River, N.T. | ♂: 118½ |
| Eureka, N.T. | ♂: 121, 122 |
| Canning Stock Route, | |
| Wells 28 and 32 | ♂: 118, 119 |
| Abydos Stn. (Fortescue R.) | ♂: 121 |
| Roebourne | ♀: 115 |
| Barrow Island | ♀: 125 |
| Ashburton R. | ♂: 122 |
| Milly Milly | —: 123 |
| Sullivan's Creek | |
| (Murchison) | —: 118 |
| 40 miles N.E. Three Rivers | |
| (Murchison) | —: 119 |
| Day Dawn | ♂: 113, 120, 123, 124, 124 |
| Yalgoo | ♂: 127 |
| Coorow | ♂: 129 |
| Kellerberrin | ♂: 125, 128 |
| Perth | ♂: 129 |
| Jandakot | ♀: 125 |

These measurements confirm the validity of *tregellasi* as a slightly larger race of the south-west. On the evidence at present available it seems best to draw the boundary line of the two races between Day Dawn (Murchison) and Yalgoo, with which I do not, however, suggest that such a sharp line can actually be drawn.

The specimen received recently from Barrow Island (A 8158) shows that this is not strictly a species of the interior as Mathews (1922-1923, p. 255) and Keast (1958d) claim. It also disposes of Mathews's argument in favour of regarding *Artamus cinereus* Vieillot from Timor as a separate species. Incidentally, the type of

tregellasi came from Rockingham on the coast, and Jandakot cannot possibly be called an interior locality either.

Artamus minor Vieillot

Little Woodswallow

Artamus minor Vieillot, Nouv. Dict. d'Hist. Nat., nouv. ed. XVII, 1817, p. 298—New South Wales (reference copied).

Eight specimens (Table LXX).

Irides brown, bill turquoise, legs dark grey, scutes black. None of the specimens shows moult.

This little woodswallow seemed to favour a more open habitat than its congeners. It was particularly common in open rocky country with only dispersed small trees. None of the other species especially favours rocky country. The five males were taken by Mr. Douglas, who took them for bats, in one shot from a cluster of six in a shallow cave. It is interesting that they are all of the same sex.

Discussion. The species shows no geographical variation (Keast 1958d).

Cracticus nigrogularis nigrogularis (Gould)

Butcher Bird

Vanga nigrogularis Gould, Synops. Birds Aust. I, 1837 (January)—New South Wales.

Cracticus nigrogularis kalgoorli Mathews, Novit. Zool. 18, 1912, p. 374—Kalgoorlie, West Australia.

For further synonyms, see Amadon (1951).

Two specimens (Table LXXI).

Irides dark brown, bill pale bluish with black tip, legs blackish grey. No moult, gonads well developed.

Not uncommon in the region.

Discussion. The species was revised by Amadon (1951) but since my conclusions differ in some points from his, I have to discuss it again in some detail.

Amadon recognised three races, *nigrogularis*, *kalgoorli* (Western Australia) and *picatus* (northern Australia); though admitting that *kalgoorli* is a slight race, which is very close to the nominate race, he retained it on the basis of a difference in bill-size, the figures in his Table 7 showing a culmen length of 40-48 (45) for 8 males and 42 for one female from New South Wales, Victoria, and South Australia (*nigrogularis*); and of 49-52 (50) for 9 males, 46-47 (47) for 5 females ascribed to *kalgoorli*.

The measurements of material in the Western Australian Museum are:

| sex | locality | wing | culmen |
|-----|------------------------|------|--------|
| ? | New South Wales | 181 | 44½ |
| ♀ | Morawa | 177 | 44½ |
| ♀ | 50 m. N.W. of Lake Way | 182 | 46 |
| ♂ | 50 m. N.W. of Lake Way | 187 | 49 |
| ♂ | 50 m. N.W. of Lake Way | 182 | 43 |
| ♀ | The Gap, Nannine | 180 | 46 |
| ? | Mingenew | 188 | 50 |
| ♂ | Wyalkatchem | 178 | 44½ |
| ♂ | Ashburton R. | 184 | 47½ |
| ? | Winding Creek | 182 | 43½ |

* The type locality Sydney as designated by Mathews (1924, 1931) must be incorrect as this species of rocky places in arid regions does not occur in the neighbourhood of that town (cf. Hindwood & McGill 1958, p. 115).

This gives, with the two specimens listed above, a range of variation from 43-50 mm and an average of 46.2 mm, as compared to, according to Amadon, 40-48 for 9 specimens from New South Wales, Victoria and South Australia, and 41-49 for 20 specimens from Queensland. The difference in mean bill length of 1½ to 2 mm, moreover measured on small samples, is evidently not sufficient to warrant recognition of a separate western race, particularly not as the variation in one locality (Lake Way) in birds of the same sex can be as much as 6 mm.

Amadon assigned specimens from the East Kimberley Division to *picatus*, but included the West Kimberley Division in the range of "*kalgoorli*", an opinion apparently based on one male specimen from Point Torment with a wing-length of 183 mm. The distribution as asserted by him is very unusual, as in other size races or populations the boundary is the desert between the Pilbara District and the Kimberley Division, and our material does not lend support to his opinion. Our material of *picatus* consists of the following specimens:

| sex | locality | wing | eulmen |
|-----|------------------------|------|-----------------------------|
| ♂ | Brock Creek, N.T. | 161 | 39 |
| ♂ | Brock Creek, N.T. | 168 | 41 |
| ♀ | Brock Creek, N.T. | 162 | 39 |
| ♂ | Wotjulum | 152 | 39½ (plumage abraded) |
| | Wotjulum | 164 | 44 |

Wotjulum is in the West Kimberley Division very close to King Sound and Point Torment, and the two males from there agree in every respect with *picatus* from the Northern Territory, so that the range of that race must be extended to include the whole Kimberley Division. I suggest that Amadon's single specimen from Point Torment may be aberrant, or may have been a straggler, or may have been incorrectly labelled, or that perhaps confusion with Point Torment in Queensland may have occurred.*

Gymnorhina tibicen longirostris Milligan Magpie.

Gymnorhina longirostris Milligan, Emu 3, 1903, p. 96.
—Ashburton River, North-Western Australia.

Two specimens (Table LXXII).

Irides bright orange brown, bill pale blue with large black tip, legs black. Weight of male 260 g, of female 230 g. The female was taken with a nest of four eggs. Testes of male very large, 22½ × 13 and 20 × 14½ mm.

Apparently uncommon, the pair collected were the only specimens encountered.

Discussion. *Gymnorhina tibicen longirostris*, of which the type is in the Western Australian Museum, is a well-marked subspecies as all recent reviewers agree (Amadon 1951, Condon 1951b).

* Material recently (May-June, 1960) collected at La Grange and Derby shows that my criticism of Amadon is unjustified and that specimens from Derby are large and belong to the nominate race. Particulars will be given in a future paper.

Chlamydera guttata Gould

Spotted Bowerbird

Chlamydera guttata Gould, Proc. Zool. Soc. Lond. 1862, p. 162—North-western Australia.

Two specimens (Table LXXIII).

Irides sepia, bill black, legs dark grey.

Not common, found in wooded rocky country near water.

Discussion. Mathews (1931), with unusually good judgment, had placed his races *subguttata*, *macdonaldi* and *carteri* (= *nova*) in the synonymy, in which he was followed by Mayr & Jennings (1952). My material is very scanty, but it supports the conclusion that there is no geographic variation in the species.

Corvus bennetti North

Little Crow

Corvus bennetti North, Vict. Nat. 7, 1901 (10 January), p. 170—Moolah, Western New South Wales.

One specimen (Table LXXIV).

Corvus orru ceciliae Mathews

Crow

Corvus coronoides ceciliae Mathews, Novit. Zool. 18, 1912, p. 442—North-West Australia, precised as Napier Broome Bay by Mathews (1924).

Three specimens (Table LXXV).

Irides white in all specimens, bill and legs black. No moult.

Discussion. Stresemann (1943) placed *ceciliae* as a race of *C. orru*, specifically separating it from *C. coronoides*, in which he was followed by Vaurie (1958). Personally I am not convinced that *C. orru* and *C. coronoides* are not conspecific. The voices of the two have much in common, and as regards the supposed overlap in range between *ceciliae* and *coronoides* it is interesting to note Serventy & Whittell's (1951) statement that in Western Australia the ranges of the two are probably mutually exclusive. Since I have not been able to make an extensive study of this difficult group, and since Serventy & Whittell believe that there is a difference in voice between *ceciliae* and *coronoides* (which I have not been able to hear, but my field experience with *ceciliae* is insufficient), it seems for the moment safest to follow the latest revisers.

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DATA ON INDIVIDUAL SPECIMENS

TABLE I

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|---------------|--------|------|-------|-------|-----------|-----------|-------------|
| A 8007 | ♀ | Tambrey | 3.VIII | 110 | ..... | 32 | 27 | 21½ | 15½ |

TABLE II

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|------------------|--------|------|------|-------|-----------|-----------|-------------|
| A 8385 | ♂ | Millstream | 4.VIII | 258 | 126 | 49 | damaged | ..... | ..... |

TABLE III

| No. | Sex | Location | Date | Wing | Tail | Tars. | Exp. cul. |
|--------|-----|------------------|--------|------|------|-------|-----------|
| A 8276 | ♂ | Millstream | 19.VII | 348 | 217 | 46½ | 76 |

TABLE IV

| No. | Sex | Location | Date | Wing | Tail | Tars. | Exp. cul. |
|--------|-----|------------------|--------|------|------|-------|-----------|
| A 8282 | ♂ | Millstream | 4.VIII | 178 | 136 | ..... | 83 |

TABLE V

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. |
|--------|-----|------------------|--------|------|------|-------|-----------|-----------|
| A 8277 | ♂ | Millstream | 19.VII | 298 | 104 | 79 | ..... | 71 |

TABLE VI

| No. | Sex | Location | Date | Wing | Tail | Tars. | Exp. cul. |
|--------|-----|------------------|--------|------|------|-------|-----------|
| A 8270 | ... | Millstream | 4.VIII | 382 | 144 | 92 | 174 |

TABLE VII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Exp. cul. |
|--------|-----|------------------|--------|------|------|-------|-----------|
| A 8106 | ♂ | Millstream | 2.VIII | 261 | 86 | 44 | 57 |
| A 8105 | ♀ | Millstream | 2.VIII | 245 | 77 | 43 | 49 |

TABLE VIII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Cul. from cere |
|--------|-----|-------------------|--------|------|------|-------|----------------|
| A 8180 | ♀ | Coolawanyah | 27.VII | 420 | 247 | 52 | 25 |

TABLE IX

| No. | Sex | Location | Date | Wing | Tail | Tars. | Cul. from cere |
|--------|-----|------------|--------|------|------|-------|----------------|
| A 8179 | + | Millstream | 20.VII | 435 | 270 | 61 | 26½ |

TABLE X

| No. | Sex | Location | Date | Wing | Tail | Tars. | Cul. from cere |
|--------|-----|------------|--------|------|------|-------|----------------|
| A 8178 | + | Millstream | 21.VII | 583 | 320 | 123 | 47½ |

TABLE XI

| No. | Sex | Location | Date | Wing | Tail | Tars. | Cul. from cere |
|--------|--------|------------|--------|------|------|-------|----------------|
| A 8177 | ♂ imm. | Tambrey | 1.VIII | 318 | 184 | 69 | 20½ |
| A 8173 | + | Millstream | 22.VII | 331 | 187 | 67 | 20 |
| A 8176 | + | Tambrey | 4.VIII | 362 | 203 | 68 | 23 |
| A 8174 | .... | Millstream | 22.VII | 358 | 205 | 70 | 24 |
| A 8175 | .... | Tambrey | 29.VII | 327 | 176 | 64 | 20 |

TABLE XII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Cul. from cere |
|--------|-----|----------|--------|------|------|-------|----------------|
| A 8107 | ♂ | Tambrey | 31.VII | 133 | 135 | 37 | 13½ |

TABLE XIII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Exp. cul. |
|--------|-----|------------|--------|------|------|-------|-----------|
| A 8286 | ♂ | Tambrey | 1.VIII | 112 | 56 | 24½ | 15 |
| A 8285 | .. | Millstream | 19.VII | 112 | 55 | 23½ | 16 |

TABLE XIV

| No. | Sex | Location | Date | Wing | Tail | Tars. | Exp. cul. | Wt. |
|--------|-----|------------|--------|------|------|-------|-----------|-----|
| A 8135 | + | Millstream | 19.VII | 106 | 94 | 18½ | 13 | 48g |
| A 8136 | + | Millstream | 19.VII | 104 | 91 | 17 | 13 | 44g |

TABLE XV

| No. | Sex | Location | Date | Wing | Tail | Tars. | Exp. cul. |
|--------|-----|------------|--------|------|------|-------|-----------|
| A 8284 | .. | Millstream | 28.VII | 91 | 103 | 13½ | 10 |

TABLE XVI

| No. | Sex | Location | Date | Wing | Tail | Tars. | Exp. cul. | Wt. |
|--------|-----|-----------------|--------|------|------|-------|-----------|------|
| A 8127 | ♀ | Millstream | 19.VII | 193 | 105 | 27 | 20 | 280g |

TABLE XVII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. |
|--------|-----|------------------|--------|------|------|-------|-----------|-----------|
| A 8108 | ♂ | Millstream | 21.VII | 205 | 73 | 26 | 23½ | 17½ |
| A 8109 | ♂ | Millstream | 26.VII | 206 | 69 | 25 | 24¾ | 19¾ |

TABLE XVIII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Exp. cul. |
|--------|-----|------------------|--------|------|------|-------|-----------|
| A 8125 | ♂ | Coolawanyah | 30.VII | 167 | 137 | .... | 14 |
| A 8124 | ♀ | Millstream | 21.VII | 166 | 139 | 25½ | 13 |
| A 8126 | ♀ | Tambrey | 29.VII | 155 | 134½ | 24 | 13¾ |

TABLE XIX

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|------------------|--------|------|------|-------|-----------|-----------|-------------|
| A 8001 | ♂ | Millstream | 18.VII | 112 | 59 | 22 | 18 | 15 | 11 |
| A 8002 | ♀ | Millstream | 18.VII | 109 | 61 | 20½ | 19 | 15 | 11 |
| A 8003 | ♀ | Tambrey | 1.VIII | 109 | 61 | 22 | 17½ | 13 | 10½ |

TABLE XX

| No. | Sex | Location | Date | Wing | Tail | Tars. | Exp. cul. | Cul. depth |
|--------|-----|-----------------|--------|------|------|-------|-----------|------------|
| A 8114 | ♀ | Millstream | 19.VII | 279 | 139 | 24 | 30½ | 17½ |
| A 8115 | ♀ | Tambrey | 3.VIII | 262 | 139 | 25 | 30¾ | 18 |

TABLE XXI

| No. | Sex | Location | Date | Wing | Tail | Tars. | Exp. cul. | Depth cul. |
|--------|-----|-----------------|--------|------|------|-------|-----------|------------|
| A 8118 | ♂ | Millstream | 28.VII | 259 | 147 | 20 | 25¼ | 16 |
| A 8117 | ♀ | Millstream | 28.VII | 266 | 144 | 20½ | 27 | 15 |

TABLE XXII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Cul. from forehead |
|--------|-----|-----------------|--------|------|------|-------|--------------------|
| A 7971 | ♂ | Millstream | 17.VII | 161 | 194 | 19 | 23 |
| A 7975 | ♂ | Millstream | 26.VII | 166 | 199 | 21 | 25 |
| A 7976 | ♂ | Tambrey | 1.VIII | 165 | 192 | 19 | 24¾ |
| A 7972 | ♀ | Millstream | 20.VII | 164 | 195 | 20¼ | 23 |
| A 7973 | ♀ | Millstream | 20.VII | 167 | 205 | 20 | 22¾ |
| A 7974 | ♀ | Tambrey | 1.VIII | 166 | 200 | 20½ | 24 |

TABLE XXIII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Cul. from fore- head feathers | Cul. from cere | Wt. |
|--------|-----|----------|--------|------|------|------------------|---|----------------------|-----|
| A 8264 | ♂ | Tambrey | 1.VIII | 97 | 99 | 12 | 12 $\frac{1}{4}$ | 9 $\frac{1}{4}$ | 29g |
| A 8265 | ♀ | Tambrey | 1.VIII | 95 | 91 | 11 $\frac{1}{4}$ | 12 $\frac{1}{4}$ | 8 $\frac{3}{4}$ | 27g |
| A 8266 | ♀ | Tambrey | 1.VIII | 97 | 90 | 11 $\frac{1}{4}$ | 12 $\frac{3}{4}$ | 10 | 26g |
| A 8267 | ♀ | Tambrey | 1.VIII | 95 | 91 | 12 | 12 | 9 $\frac{1}{2}$ | 27g |
| A 8268 | ♂ | Tambrey | 1.VIII | 94 | 88 | 11 $\frac{1}{4}$ | 12 | 9 $\frac{1}{2}$ | 26g |

TABLE XXIV

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|------------|--------|------|------|------------------|--------------|--------------|------------------|
| A 7982 | ♂ | Millstream | 27.VII | 198 | 157 | 20 | 29 | 20 | 16 $\frac{1}{2}$ |
| A 7981 | ♂ | Tambrey | 3.VIII | 195 | 163 | 19 $\frac{1}{2}$ | 28 | 20 | 16 $\frac{1}{4}$ |

TABLE XXV

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|------------|--------|------|------|-------|--------------|------------------|----------------|
| A 7983 | ♂ | Millstream | 25.VII | 97 | 65 | 17 | 17 | 11 $\frac{1}{2}$ | 10 |

TABLE XXVI

| No. | Sex | Location | Date | Wing | Tail | Wt. |
|--------|------|----------|--------|------|------|------|
| A 8361 | ♀ | Tambrey | 31.VII | 232 | 133 | 250g |
| A 8362 | | Tambrey | 4.VIII | 226 | 134 | .... |

TABLE XXVII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. |
|--------|-----|-------------|--------|------|-------------------|-------|------------------|
| A 8379 | ♂ | Mt. Herbert | 24.VII | 129 | 116 $\frac{1}{2}$ | .... | .... |
| A 8380 | ♂ | Tambrey | 30.VII | 135 | 123 | 24 | 15 $\frac{1}{2}$ |

TABLE XXVIII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|-------------|--------|------|------|-------|--------------|--------------|-----------------|
| A 8013 | ♂ | Millstream | 19.VII | 212 | 146 | 20 | 20 | 7 | 7 |
| A 8014 | ♀ | Mt. Herbert | 21.VII | 217 | 150 | 19 | 22 | 8 | 7 $\frac{1}{4}$ |
| A 8015 | ♀ | Millstream | 26.VII | 222 | 144 | .. | 22 | 9 | 7 |

TABLE XXIX

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|------------|--------|------|------|------------------|------------------|--------------|----------------|
| A 8004 | ♂ | Millstream | 19.VII | 203 | 134 | 29 | 81 | 65 | 67 |
| A 8005 | ♂ | Millstream | 19.VII | 210 | 132 | 28 | 78 | 66 | 64 |
| A 8006 | ♂ | Millstream | 4.VIII | 205 | 130 | 30 $\frac{1}{2}$ | 79 $\frac{1}{2}$ | 68 | 64 |

TABLE XXX

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|--------|------------|--------|------|------|-------|--------------|--------------|----------------|
| A 8058 | ♂ | Tambrey | 1.VIII | 110 | 65½ | 15¼ | 43 | 38½ | 34¾ |
| A 8059 | ♂ | Tambrey | 4.VIII | 103 | 69 | 15 | 44½ | 38 | 35½ |
| A 8056 | ♂ | Millstream | 19.VII | 103 | 67 | 15 | 44 | 38 | 34¾ |
| A 8057 | ♀ juv. | Tambrey | 1.VIII | 100 | 67 | 15 | 41 | 36¾ | 33¼ |

TABLE XXXI

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|------------|--------|------|------|-------|--------------|--------------|----------------|
| A 8229 | ♀ | Millstream | 21.VII | 104 | 82 | 11½ | 48 | 42 | 39 |

TABLE XXXII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|-------------|--------|------|------------------|------------------|------------------|------------------|-----------------|
| A 8031 | ♂ | Millstream | 24.VII | 80 | 49 | 23 $\frac{1}{4}$ | 14 $\frac{1}{2}$ | 12 | 9 $\frac{3}{4}$ |
| A 8032 | ♂ | Coolawanyah | 30.VII | 78 | 53 | 23 | 14 $\frac{1}{2}$ | 11 | 9 $\frac{1}{4}$ |
| A 8034 | ♂ | Coolawanyah | 30.VII | 79 | 52 $\frac{1}{2}$ | ... | 14 | 12 | 9 $\frac{1}{4}$ |
| A 8035 | ♂ | Coolawanyah | 30.VII | 77 | 48 | 20 $\frac{3}{4}$ | 13 $\frac{3}{4}$ | 11 $\frac{3}{4}$ | 9 $\frac{1}{4}$ |
| A 8033 | ♂ | Coolawanyah | 30.VII | 73 | 47 | 22 $\frac{1}{2}$ | 14 $\frac{1}{4}$ | 12 | 9 |

TABLE XXXIII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|------------|--------|------|------|------------------|------------------|-----------------|-----------------|
| A 8262 | ♂ | Tambrey | 1.VIII | 102 | 43 | .... | 11 | 6 | 5 $\frac{1}{4}$ |
| A 8263 | ♂ | Tambrey | 1.VIII | 99 | 42 | 10 $\frac{1}{4}$ | 8 $\frac{1}{4}$ | 6 $\frac{1}{4}$ | 5 |
| A 8260 | ♂ | Millstream | 20.VII | 97 | 40 | .... | 9 $\frac{3}{4}$ | 5 $\frac{1}{2}$ | 4 $\frac{1}{2}$ |
| A 8261 | ♂ | Tambrey | 1.VIII | 102 | 46 | 12 | 11 $\frac{1}{2}$ | 6 $\frac{1}{2}$ | 5 $\frac{1}{2}$ |

TABLE XXXIV

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|------|------------|--------|------------------|------------------|-------|------------------|------------------|-----------------|
| A 8081 | ♂ | Roy Hill | 11.VII | 87 $\frac{1}{2}$ | 60 | 25 | 16 | 11 $\frac{3}{4}$ | 9 $\frac{1}{2}$ |
| A 8085 | ♂ | Millstream | 21.VII | 88 | 59 $\frac{1}{2}$ | 24 | 15 | 12 $\frac{3}{4}$ | 9 $\frac{1}{2}$ |
| A 8084 | ♂ | Tambrey | 29.VII | 84 $\frac{1}{2}$ | 58 $\frac{1}{2}$ | 24 | 16 $\frac{3}{4}$ | 12 $\frac{1}{2}$ | 10 |
| A 8083 | juv. | Tambrey | 29.VII | .... | .... | .... | .... | .... | .... |
| A 8082 | juv. | Millstream | 24.VII | .... | .... | .... | .... | .... | .... |

TABLE XXXV

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|------------|--------|------|------|------------------|------------------|------------------|------------------|
| A 8112 | (♂) | Millstream | 21.VII | 104 | 81 | 20 $\frac{3}{4}$ | 15 $\frac{1}{4}$ | 12 $\frac{1}{4}$ | 10 $\frac{1}{4}$ |
| A 8113 | ♀ | Millstream | 22.VII | 95 | 72 | 19 | 16 $\frac{1}{4}$ | 12 $\frac{1}{4}$ | 10 $\frac{1}{4}$ |

TABLE XXXVI

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|--------|-------------|--------|------|------|------------------|------------------|------------------|------------------|
| A 8119 | ♂ | Millstream | 17.VII | 193 | 145 | 28 | 34 | 25 | 20 |
| A 8122 | ♂ | Tambrey | 29.VII | 197 | 143 | 30 | 30 $\frac{1}{2}$ | 24 $\frac{1}{2}$ | 20 |
| A 8123 | ♂ imm. | Millstream | 23.VII | 186 | 139 | 26 $\frac{3}{4}$ | 29 | 24 | 20 |
| A 8120 | ♀ | Mt. Herbert | 24.VII | 188 | 147 | 29 | 27 | 21 $\frac{1}{2}$ | 18 $\frac{1}{2}$ |
| A 8121 | ♀ | Mt. Herbert | 25.VII | 201 | 142 | 29 | 28 $\frac{1}{4}$ | 23 | 19 |

TABLE XXXVII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|------------|--------|------|------|-------|-----------|------------------|-------------|
| A 8066 | ♂ | Millstream | 19.VII | 103 | 101 | 29 | 31 | 25 $\frac{1}{2}$ | 20 |
| A 8067 | ♀ | Millstream | 19.VII | 110 | 105 | 33 | 35 | 31 | 25 |

TABLE XXXVIII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|------------|--------|------|------------------|------------------|------------------|------------------|-------------|
| A 8009 | ♂ | Millstream | 19.VII | 76 | 67 | 26 | 20 | 14 $\frac{3}{4}$ | 12 |
| A 8008 | ♂ | Millstream | 19.VII | 78 | 66 | 24 | 21 $\frac{1}{2}$ | 15 | 12 |
| A 8012 | ♂ | Millstream | 24.VII | 77 | 68 | 25 $\frac{1}{2}$ | 20 | 15 | 12 |
| A 8010 | ♀ | Millstream | 20.VII | 73 | 60 $\frac{1}{2}$ | 26 | 21 $\frac{1}{2}$ | 15 $\frac{1}{4}$ | 12 |
| A 8011 | ♀ | Millstream | 22.VII | 72 | 62 | 24 $\frac{1}{2}$ | 20 | 14 $\frac{1}{2}$ | 11 |

TABLE XXXIX

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|------------|--------|------------------|------|------------------|------------------|-----------------|-----------------|
| A 8226 | ♀ | Millstream | 22.VII | 48 $\frac{1}{2}$ | 49 | 18 $\frac{1}{2}$ | 12 $\frac{1}{4}$ | 10 | 7 $\frac{1}{2}$ |
| A 8227 | ♀ | Millstream | 24.VII | 45 | 44 | 18 $\frac{1}{4}$ | 12 | 9 $\frac{1}{2}$ | 7 $\frac{1}{4}$ |

TABLE XL

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|----------|--------|------------------|------------------|------------------|------------------|-----------------|-----------------|
| A 8203 | ♂ | Tambrey | 28.VII | 54 | 41 | 18 | 11 | 8 $\frac{1}{2}$ | 6 |
| A 8201 | ♀ | Tambrey | 28.VII | 56 | 39 $\frac{1}{2}$ | 16 $\frac{1}{2}$ | 11 $\frac{1}{4}$ | 8 $\frac{1}{4}$ | 5 $\frac{3}{4}$ |
| A 8202 | ♀ | Tambrey | 28.VII | 57 $\frac{1}{2}$ | 42 | 17 | 11 $\frac{1}{4}$ | 8 | 6 |

TABLE XLI

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|------------|--------|------------------|------------------|-------|-----------------|-----------------|-------------|
| A 8204 | ♂ | Millstream | 19.VII | 50 $\frac{1}{2}$ | 34 | 16 | 8 $\frac{1}{2}$ | 6 | 4 |
| A 8205 | ♂ | Millstream | 19.VII | 50 $\frac{1}{2}$ | 31 $\frac{1}{2}$ | 16 | 8 $\frac{1}{4}$ | 6 | 4 |
| A 8206 | ♂ | Tambrey | 1.VIII | 50 | 31 $\frac{1}{2}$ | 15 | 8 | 6 | 4 |
| A 8207 | ♀ | Millstream | 18.VII | 50 | 31 $\frac{1}{2}$ | 15 | 8 $\frac{1}{4}$ | 6 | 4 |
| A 8203 | ♀ | Millstream | 17.VII | 49 | 29 | 15 | 8 | 6 $\frac{1}{4}$ | 4 |

TABLE XLII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-------|------------|--------|------|------|-------|-----------|-----------|-------------|
| A 8080 | ♂ | Millstream | 21.VII | 89 | 75½ | 25½ | 17 | 13½ | 10 |
| A 8078 | ♂ | Millstream | 19.VII | 80 | 68 | 25 | ..... | ..... | ..... |
| A 8079 | ♂ | Millstream | 19.VII | 91 | 75 | 31 | 17½ | 14 | 10 |
| A 8077 | | Millstream | 26.VII | 77 | 67 | 23½ | 15 | 12 | 9½ |

TABLE XLIII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-------|----------|--------|------|------|-------|-----------|-----------|-------------|
| A 8246 | ♂ | Tambrey | 2.VIII | 54½ | 67 | 14½ | 14 | 11 | 8½ |
| A 8248 | ♂ | Tambrey | 4.VIII | 55½ | 60 | 14¾ | 15½ | 11¼ | 8½ |
| A 8249 | ♂ | Tambrey | 5.VIII | 55 | 65 | 15 | 15¼ | 11 | 8½ |
| A 8244 | ♂ | Tambrey | 1.VIII | 55 | 63 | 15 | 14 | 11½ | 9¼ |
| A 8247 | ♂ | Tambrey | 2.VIII | 55 | 58 | 15 | ..... | ..... | ..... |
| A 8250 | ♂ | Tambrey | 5.VIII | 57 | 66½ | 15¼ | 14½ | 11½ | 8¼ |
| A 8245 | | Tambrey | 1.VIII | 55 | 66 | 14¼ | 15½ | 12½ | 8¾ |

TABLE XLIV

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|-------------|--------|------|------|-------|-----------|-----------|-------------|
| A 8164 | ♂ | Mt. Herbert | 25.VII | 62½ | 83½ | 25½ | 16 | 12 | 9 |
| A 8159 | ♂ | Millstream | 25.VII | 64 | 74 | 25¼ | 15 | 12½ | 8½ |
| A 8161 | ♂ | Tambrey | 3.VIII | 63 | 80 | 25 | 15¼ | 11½ | 9 |
| A 8165 | ♂ | Tambrey | 28.VII | 60 | 76 | 23 | 15 | 12¼ | 9 |
| A 8160 | ♂ | Tambrey | 3.VIII | 62 | 73 | 25¼ | 16¼ | 13 | 8¾ |
| A 8166 | ♂ | Tambrey | 5.VIII | 61 | 80 | 24¾ | 16 | 12¼ | 8½ |

TABLE XLIVa

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|-------------|-----|----------|--------------|------|-------|-------|-----------|-----------|-------------|
| AMNH 598110 | ♂ | Borewell | 31.VII. 1909 | 64 | 85 | 23½ | 14¼ | 11 | 8 |
| AMNH 598114 | ♂ | Borewell | 5.VIII.1909 | 57 | 76 | 23¼ | 12½ | 10½ | 7¼ |
| AMNH 598115 | ♂ | Borewell | 5.VIII.1909 | 61 | 81 | 23¼ | 14 | 11¾ | 8¼ |
| AMNH 598113 | ♂ | Borewell | 6.VIII.1909 | 58 | 81½ | 24 | 14 | 10¾ | 8 |
| AMNH 265500 | ♂ | Borewell | 5.IX. 1909 | 58 | 76 | 23½ | 14 | 12 | 8¾ |
| A 5859 | ♂ | Well 48 | 27.VI. 1943 | 61 | ..... | 22½ | 13 | 10 | 8 |
| A 5861 | ♂ | Well 48 | 20.VII. 1943 | 57 | 82 | 22½ | 13½ | 11 | 7¾ |
| A 5863 | ♂ | Well 48 | 24.VII. 1943 | 58 | 79 | 24¼ | 13½ | 10¼ | 8¼ |
| A 5867 | ♂ | Well 48 | 24.VII. 1943 | 58 | 81 | 23¼ | 13¼ | 10¾ | 8 |
| A 5866 | ♂ | Well 48 | 10.VIII.1943 | 60½ | 85 | 23 | 13 | 10 | 7½ |
| A 4034 | ♂ | Well 35 | 27.X. 1930 | 59 | 76 | 22½ | 13 | 11 | 7¾ |
| A 5860 | ♂ | Well 48 | 22.VI. 1943 | 58 | 77 | 22 | 14 | 11 | 8¼ |
| A 5862 | ♂ | Well 48 | 3.VII. 1943 | 59 | 77½ | 22 | 12½ | 10 | 7¼ |
| A 5856 | ♂ | Well 48 | 23.VII. 1943 | 57 | ..... | 23 | 13 | 10½ | 7½ |
| A 5864 | ♂ | Well 48 | 24.VII. 1943 | 56 | 78½ | 22½ | 12½ | 9½ | 7 |

| | | | | | | | | | |
|-------------------------|-------|-------|-------|------|------|------|------|------|-----|
| <i>whitei</i> (6) ..... | ..... | ..... | ..... | 62.1 | 77.8 | 24.8 | 15.6 | 12.3 | 8.8 |
| <i>oweni</i> (5) ..... | ..... | ..... | ..... | 59.6 | 79.9 | 23.5 | 13.8 | 11.2 | 8.1 |
| <i>rufus</i> (10)..... | ..... | ..... | ..... | 58.4 | 79.5 | 22.8 | 13.1 | 10.4 | 7.7 |

TABLE XLV

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|------------|--------|------------------|------------------|------------------|------------------|-----------------|-----------------|
| A 8220 | ♂ | Millstream | 22.VII | 39 $\frac{1}{2}$ | 66 | 15 | 10 | 8 | 5 $\frac{1}{2}$ |
| A 8221 | ♂ | Millstream | 22.VII | 39 | 74 | 15 | 10 $\frac{1}{4}$ | 8 | 5 $\frac{3}{4}$ |
| A 8222 | ♂ | Tambrey | 28.VII | 40 | 63 | 15 | 10 $\frac{3}{4}$ | 7 $\frac{1}{2}$ | 5 |
| A 8223 | ♂ | Tambrey | 30.VII | 38 $\frac{1}{2}$ | 67 | 15 | 10 $\frac{1}{4}$ | 8 $\frac{1}{2}$ | 6 |
| A 8224 | ♂ | Tambrey | 1.VIII | 38 $\frac{1}{2}$ | 66 $\frac{1}{2}$ | 14 | 10 | 8 | 5 $\frac{1}{2}$ |
| A 8225 | ♂ | Tambrey | 4.VIII | 39 | 76 | 14 $\frac{1}{2}$ | 10 $\frac{1}{4}$ | 8 | 5 $\frac{3}{4}$ |

TABLE XLVI

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-------------|------------|--------|------------------|------------------|------------------|------------------|-----------------|-----------------|
| A 8334 | ♂ | Millstream | 19.VII | 47 $\frac{1}{2}$ | 70 $\frac{1}{2}$ | 21 $\frac{1}{2}$ | 12 | 9 $\frac{1}{4}$ | 5 $\frac{3}{4}$ |
| A 8337 | ♂ | Millstream | 19.VII | 48 | 63 | 21 | 11 $\frac{1}{4}$ | 8 $\frac{1}{4}$ | 6 |
| A 8338 | ♂ | Tambrey | 29.VII | 48 | 66 $\frac{1}{2}$ | 21 | 12 | 9 | 6 |
| A 8336 | ♂ in change | Tambrey | 2.VIII | 47 | 65 | 22 | 12 $\frac{1}{2}$ | 9 $\frac{1}{2}$ | 6 |
| A 8335 | + | Millstream | 19.VII | 46 | 61 | 21 | 12 $\frac{1}{2}$ | 9 | 6 $\frac{1}{4}$ |
| A 8339 | + | Tambrey | 29.VII | 48 | 64 | 20 $\frac{1}{2}$ | 11 $\frac{1}{2}$ | 9 | 6 |

TABLE XLVII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|------------|--------|------------------|------|------------------|------------------|-----------------|-----------------|
| A 8288 | ♂ | Tambrey | 29.VII | 46 $\frac{1}{2}$ | 58 | 18 $\frac{1}{4}$ | 11 $\frac{1}{4}$ | 8 $\frac{3}{4}$ | 6 $\frac{1}{4}$ |
| A 8289 | ♂ | Tambrey | 1.VIII | 46 | ... | 18 $\frac{3}{4}$ | 11 $\frac{1}{4}$ | 9 | 6 $\frac{1}{2}$ |
| A 8287 | + | Millstream | 21.VII | 45 | 61 | 18 $\frac{3}{4}$ | 11 $\frac{1}{2}$ | 8 $\frac{1}{2}$ | 5 $\frac{1}{2}$ |
| A 8290 | + | Tambrey | 2.VIII | 47 | 59 | 19 $\frac{1}{4}$ | 11 $\frac{1}{2}$ | 9 | 6 |

TABLE XLVIII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|------------|--------|------------------|------------------|------------------|------------------|------------------|-----------------|
| A 8188 | ♂ | Millstream | 28.VII | 69 | 40 | 19 | 15 | 12 | 8 $\frac{1}{4}$ |
| A 8190 | ♂ | Tambrey | 1.VIII | 69 $\frac{1}{2}$ | 38 $\frac{1}{2}$ | 18 $\frac{1}{4}$ | 14 $\frac{1}{2}$ | 12 $\frac{1}{2}$ | 9 $\frac{3}{4}$ |
| A 8191 | ♂ | Tambrey | 4.VIII | 69 | 37 $\frac{1}{2}$ | 18 $\frac{3}{4}$ | 14 $\frac{1}{2}$ | 12 $\frac{1}{4}$ | 8 $\frac{1}{2}$ |
| A 8192 | ♂ | Tambrey | 4.VIII | 68 | 37 | 18 $\frac{1}{4}$ | 15 | 12 | 8 |
| A 8189 | + | Millstream | 28.VII | 67 | 40 $\frac{1}{2}$ | ... | 14 | 10 $\frac{3}{4}$ | 8 |
| A 8193 | + | Tambrey | 4.VIII | 68 $\frac{1}{2}$ | 39 | 18 $\frac{1}{2}$ | 14 $\frac{1}{4}$ | 11 $\frac{3}{4}$ | 8 $\frac{1}{2}$ |

TABLE XLIX

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|------|------------|--------|------------------|------------------|------------------|------------------|------------------|-----------------|
| A 8137 | ♂ | Millstream | 21.VII | 97 $\frac{1}{2}$ | 66 | 22 | ... | ... | ... |
| A 8139 | ♂ | Millstream | 22.VII | 95 | 66 | 22 | 17 $\frac{1}{4}$ | 12 $\frac{1}{4}$ | 9 $\frac{3}{4}$ |
| A 8136 | ♂ | Millstream | 23.VII | 95 | 68 | 22 | 17 $\frac{1}{2}$ | 13 $\frac{1}{2}$ | 10 |
| A 8140 | ♂ | Tambrey | 28.VII | 94 | 66 | 23 | 16 $\frac{3}{4}$ | 12 $\frac{1}{2}$ | 9 $\frac{1}{2}$ |
| A 8138 | imm. | Millstream | 26.VII | 89 | 60 $\frac{1}{2}$ | 22 $\frac{1}{2}$ | 16 $\frac{1}{2}$ | 12 $\frac{1}{4}$ | 9 |
| A 8141 | + | Tambrey | 1.VIII | 88 | 58 $\frac{1}{2}$ | 21 | 15 $\frac{1}{4}$ | 12 | 9 |

TABLE L

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-------|-----------------|--------|------------------|------|------------------|------------------|-----------------|-----------------|
| A 8137 | 10-10 | Millstream | 24.VII | 75 | 88 | 16 | 12 | 6 $\frac{3}{4}$ | 5 $\frac{1}{4}$ |
| A 8138 | | Tambrey | 1.VIII | 72 $\frac{1}{2}$ | 63 | 16 $\frac{3}{4}$ | 11 $\frac{1}{2}$ | 6 $\frac{1}{2}$ | 5 |

TABLE LI

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|------------------|------------------|--------|------|------|------------------|------------------|------------------|-----------------|
| A 7984 | 4-10 10-10 10-10 | Mt. Herbert | 24.VII | 97 | 101 | 25 $\frac{1}{2}$ | 16 $\frac{3}{4}$ | 11 $\frac{1}{4}$ | 9 $\frac{3}{4}$ |
| A 7986 | | Tambrey | 28.VII | 99 | 99 | 24 | 17 $\frac{1}{4}$ | 11 | 9 $\frac{1}{4}$ |
| A 7988 | | Tambrey | 31.VII | 101 | 104 | 25 | 16 $\frac{1}{2}$ | 10 $\frac{1}{4}$ | 8 $\frac{3}{4}$ |
| A 7987 | | Millstream | 19.VII | 99 | 105 | 24 $\frac{1}{2}$ | 17 | 10 $\frac{1}{4}$ | 9 |
| A 7985 | | Tambrey | 29.VII | 100 | 107 | 25 $\frac{1}{4}$ | 15 $\frac{1}{2}$ | 11 | 9 $\frac{1}{2}$ |

TABLE LII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-------------------|-----------------|--------|------|------|------------------|------------------|------------------|-----------------|
| A 8097 | 10-10 10-10 10-10 | Millstream | 21.VII | 94 | 70 | 21 $\frac{1}{2}$ | 14 $\frac{3}{4}$ | 10 | 8 $\frac{3}{4}$ |
| A 8096 | | Tambrey | 3.VIII | 94 | 69 | 22 | .... | .... | .... |
| A 8094 | | Marillana | 12.VII | 87 | 67 | 22 $\frac{1}{2}$ | 15 $\frac{1}{4}$ | 12 $\frac{1}{2}$ | 9 |
| A 8095 | | Millstream | 22.VII | 88 | 68 | 22 | 15 $\frac{3}{4}$ | 12 $\frac{1}{4}$ | 9 |
| A 8098 | | Millstream | 22.VII | 93 | 70 | 22 | 15 $\frac{1}{2}$ | 12 $\frac{3}{4}$ | 9 $\frac{3}{4}$ |

TABLE LIII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-------------------|------------------|--------|------|------------------|------------------|------------------|------------------|------------------|
| A 8061 | 10-10 10-10 10-10 | Wittenoom | 15.VII | 121 | 100 | 30 | 26 $\frac{1}{4}$ | 20 $\frac{3}{4}$ | 15 $\frac{1}{2}$ |
| A 8062 | | Millstream | 19.VII | 119 | 96 $\frac{1}{2}$ | 30 $\frac{3}{4}$ | 27 $\frac{1}{2}$ | 20 | 16 |
| A 8063 | | Millstream | 19.VII | 120 | 102 | 31 | 25 | 21 $\frac{1}{2}$ | 15 $\frac{1}{4}$ |
| A 8064 | | Mt. Herbert | 24.VII | 118 | 97 | 30 $\frac{1}{2}$ | 25 $\frac{1}{4}$ | 20 $\frac{1}{2}$ | 15 $\frac{1}{4}$ |
| A 8065 | | Millstream | 26.VII | 118 | 97 | 30 $\frac{3}{4}$ | 25 $\frac{1}{2}$ | 21 $\frac{1}{4}$ | 15 |

TABLE LIV

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-------------------|--------------|--------|------|------|------------------|------------------|------------------|------------------|
| A 8366 | 10-10 10-10 10-10 | Tambrey | 2.VIII | 108 | 83 | 28 | 20 $\frac{1}{4}$ | 18 | 12 $\frac{3}{4}$ |
| A 8368 | | Tambrey | 3.VIII | 106 | 85 | 26 $\frac{3}{4}$ | 19 | .... | 12 |
| A 8367 | | Tambrey | 2.VIII | 102 | 71 | 28 | 19 | 15 $\frac{1}{2}$ | 11 |

TABLE LV

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|---------|-----------------|--------|------|------------------|------------------|------------------|------------------|------------------|
| A 8100 | ♂ | Tambrey | 1.VIII | 95 | 62 | 23 $\frac{1}{2}$ | 17 $\frac{1}{4}$ | 15 | 12 |
| A 8104 | (♂) | Tambrey | 28.VII | 93 | 61 | 22 $\frac{1}{4}$ | 16 $\frac{1}{4}$ | 13 | 11 |
| A 8101 | (♂) | Tambrey | 1.VIII | 96 | 63 | 22 $\frac{3}{4}$ | 19 | 15 | 12 |
| A 8103 | = | Millstream | 19.VII | 92 | 61 | 23 | 17 $\frac{3}{4}$ | 14 | 12 |
| A 8102 | = | Tambrey | 1.VIII | 93 | 59 | 22 $\frac{1}{2}$ | 18 $\frac{1}{4}$ | 13 $\frac{3}{4}$ | 12 |
| A 8099 | + = ♂ ? | Millstream | 26.VII | 88 | 63 $\frac{1}{2}$ | 22 | 18 $\frac{1}{4}$ | 15 | 12 $\frac{1}{2}$ |

TABLE LVI

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|---------------|--------|------------------|------------------|------------------|------------------|-----------------|-------------|
| A 8235 | ♂ | Tambrey .. | 27.VII | 62 | 30 $\frac{1}{2}$ | 18 | 10 | 7 $\frac{1}{4}$ | 5 |
| A 8233 | = | Tambrey ... | 28.VII | 62 | 28 $\frac{1}{2}$ | 19 | 10 $\frac{1}{4}$ | 7 $\frac{1}{4}$ | 5 |
| A 8236 | = | Tambrey ... | 28.VII | 62 | 28 $\frac{1}{2}$ | 19 | 8 | 6 | 5 |
| A 8234 | = | Tambrey ... | 29.VII | 65 | 31 | 19 $\frac{1}{4}$ | 10 $\frac{3}{4}$ | 6 $\frac{3}{4}$ | 5 |
| A 8232 | ? | Millstream .. | 19.VII | 62 $\frac{1}{2}$ | 33 $\frac{1}{2}$ | 19 | 10 $\frac{1}{4}$ | 6 $\frac{1}{4}$ | 5 |

TABLE LVII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|-----------------------|--------|------|------------------|------------------|------------------|-----------------|-----------------|
| A 8230 | = | Dale Gorge Creek | 13.VII | 63 | 29 | 20 $\frac{1}{4}$ | 11 | 7 $\frac{3}{4}$ | 6 |
| A 8231 | = | Mt. Herbert | 24.VII | 62 | 31 $\frac{1}{2}$ | 21 | 10 $\frac{1}{2}$ | 7 | 5 $\frac{3}{4}$ |

TABLE LVIII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|-----------------|--------|------------------|------------------|------------------|------------------|------------------|-----------------|
| A 8068 | ♂ | Millstream | 22.VII | 88 | 63 | 20 | 17 $\frac{3}{4}$ | 14 | 10 |
| A 8069 | ♂ | Millstream | 24.VII | 85 | 62 $\frac{1}{2}$ | 19 $\frac{3}{4}$ | 16 $\frac{3}{4}$ | 12 $\frac{1}{2}$ | 9 $\frac{1}{2}$ |
| A 8110 | ♂ | Mt. Herbert .. | 25.VII | 81 | 61 | 20 | 16 $\frac{1}{4}$ | 13 $\frac{1}{4}$ | 9 $\frac{3}{4}$ |
| A 8070 | = | Millstream | 24.VII | 86 $\frac{1}{2}$ | 63 | 19 $\frac{1}{2}$ | 17 | 13 $\frac{1}{2}$ | 10 |
| A 8111 | = | Mt. Herbert .. | 25.VII | 83 | 58 $\frac{1}{2}$ | 19 | 17 | 14 | 10 |

TABLE LIX

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|-----------------|--------|------------------|------------------|------------------|------------------|------------------|------------------|
| A 8208 | ♂ | Millstream .. | 21.VII | 68 $\frac{1}{2}$ | 51 $\frac{1}{2}$ | 17 | 19 $\frac{1}{2}$ | 15 $\frac{3}{4}$ | 10 $\frac{3}{4}$ |
| A 8210 | ♂ | Millstream | 22.VII | 67 | 51 | 18 | 18 $\frac{1}{2}$ | 14 $\frac{1}{2}$ | 10 $\frac{1}{2}$ |
| A 8211 | ♂ | Mt. Herbert .. | 25.VII | 73 | 60 | 19 | 19 $\frac{1}{4}$ | 15 | 9 $\frac{1}{2}$ |
| A 8212 | ♂ | Mt. Herbert .. | 26.VII | 62 | 46 | 16 | 18 | 14 $\frac{1}{2}$ | 9 |
| A 8214 | ♂ | Tambrey .. | 31.VII | 68 | 53 | 16 | 18 $\frac{1}{2}$ | 15 | 10 $\frac{1}{4}$ |
| A 8213 | = | Tambrey .. | 28.VII | 60 | 46 | 15 $\frac{3}{4}$ | 16 | 12 $\frac{3}{4}$ | 8 $\frac{1}{2}$ |
| A 8215 | = | Tambrey .. | 31.VII | 61 | 49 | 15 $\frac{1}{4}$ | 16 $\frac{3}{4}$ | 14 | 9 |
| A 8209 | = | Mt. Herbert .. | 24.VII | 63 | 51 | 17 $\frac{3}{4}$ | 17 | 13 | 8 $\frac{1}{2}$ |

TABLE LX

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|---------------------------|------|---------------------------|---------------|------------------|------------------|------------------|------------------|------------------|------------------|
| <i>forresti</i> | | | | | | | | | |
| 7729* | ♂ | Lewis Island | 27.VI. 1902 | 96 | 81 | 26 | 22 | 16 $\frac{1}{4}$ | 11 |
| A 8023 | ♂ | Barrow Island | 18.XI. 1958 | 82 | 73 | 23 $\frac{1}{4}$ | 18 $\frac{1}{2}$ | 14 | 9 $\frac{1}{4}$ |
| A 8027 | ♂ | Barrow Island | 21.IX. 1958 | 94 | 82 | 25 | 20 $\frac{1}{2}$ | 15 $\frac{1}{2}$ | 10 |
| A 8028 | ♂ | Barrow Island | 20.IX. 1958 | 82 | 72 $\frac{1}{2}$ | 21 | 18 $\frac{3}{4}$ | 15 | 10 |
| A 8022 | ♂ | Barrow Island | 18.IX. 1958 | 84 | 76 | 22 $\frac{3}{4}$ | 18 | 13 | 8 |
| A 8029 | ♂ | Barrow Island | 21.IX. 1958 | 84 | 70 | 24 $\frac{1}{2}$ | 19 | 13 $\frac{3}{4}$ | 8 |
| A 8021 | ♂ | Onslow | 16.IX. 1958 | 93 | 80 $\frac{1}{2}$ | 25 $\frac{1}{4}$ | 19 $\frac{3}{4}$ | 15 $\frac{3}{4}$ | 10 |
| A 8228 | ♂ | Millstream | 26.VII. 1958 | 83 | 73 | 24 $\frac{3}{4}$ | 18 $\frac{3}{4}$ | 14 | 9 $\frac{1}{2}$ |
| A 8018 | ♂ | Millstream | 28.VII. 1958 | 82 $\frac{1}{2}$ | 72 | 22 | 19 | 13 $\frac{1}{2}$ | 9 |
| A 8019 | ♂ | Tambrey | 31.VII. 1958 | 82 | 76 | 22 $\frac{1}{2}$ | 18 $\frac{3}{4}$ | 14 | 9 $\frac{1}{2}$ |
| A 8016 | ♂ | Tambrey | 27.VII. 1958 | 81 | 75 | 22 $\frac{3}{4}$ | 15 | 10 | 10 |
| A 8017 | ♂ | Tambrey | 29.VII. 1958 | 92 | 80 | 24 | 20 | 16 | 11 |
| A 8020 | imm. | Tambrey | 30.VII. 1958 | 82 $\frac{1}{2}$ | 73 | 21 $\frac{1}{2}$ | 19 | 14 | 9 $\frac{3}{4}$ |
| A 8309 | juv. | Coolawanyah | 30.VII. 1958 | 81 | 72 $\frac{1}{2}$ | 23 $\frac{1}{2}$ | 19 | 14 $\frac{1}{2}$ | 10 |
| 7730 | ♂ | Marble Bar | 3.IV. 1901 | 87 | 75 | 23 | 19 | 14 | 9 |
| 9505 | ♂ | Marble Bar | 22.V. 1901 | 92 | 90 | 23 $\frac{1}{2}$ | 18 $\frac{3}{4}$ | 15 | 10 |
| A 4081 | ♂ | Well 50 | 12.II. 1931 | 86 $\frac{1}{2}$ | 78 $\frac{1}{2}$ | 25 $\frac{1}{2}$ | 19 | 14 | 9 $\frac{1}{4}$ |
| A 4078 | ♂ | Well 37 | 15.XI. 1930 | 86 | 76 | 22 $\frac{1}{4}$ | 18 | 13 $\frac{1}{2}$ | 9 |
| A 4077† | ♂ | Well 33 | 13.X. 1930 | 89 | 76 | 23 | 21 | 15 $\frac{1}{2}$ | 11 |
| A 4074 | ♂ | Well 28 | 7.VIII. 1930 | 92 $\frac{1}{2}$ | 77 | 24 | 19 | 14 | 10 |
| A 4073 | ♂ | Well 26 | 15.VII. 1930 | 87 | 74 | 24 | 17 | 13 | 9 $\frac{3}{4}$ |
| 9307 | ♂ | Sullivan Creek, Murchison | Feb., 1908 | 97 | 88 | 25 | 19 $\frac{1}{2}$ | 15 $\frac{1}{4}$ | 9 $\frac{1}{2}$ |
| 1525 | ♂ | Lawlers, East Murchison | 5.XI. 1899 | 94 | 80 | 24 $\frac{1}{4}$ | 20 | 15 $\frac{1}{2}$ | 10 |
| 5376 | ♂ | Lake Austin | 28.III. 1903 | 89 | 77 | 24 | 18 $\frac{1}{2}$ | 14 | 9 $\frac{1}{2}$ |
| 5375 | juv. | Lake Austin | 15.III. 1903 | 85 | 77 | 24 | 18 $\frac{1}{2}$ | 13 $\frac{1}{2}$ | 8 $\frac{3}{4}$ |
| 5378 | ♂ | Lake Austin | 16.III. 1903 | 85 | 74 | 22 | 19 | 14 | 11 |
| 5377 | ♂ | Lake Austin | 26.III. 1903 | 84 $\frac{1}{2}$ | 76 | 23 $\frac{1}{2}$ | 17 | 12 $\frac{1}{2}$ | 8 $\frac{1}{2}$ |
| <i>forresti—virescens</i> | | | | | | | | | |
| A 8396 | ♂ | Carnarvon | 11.VIII. 1959 | 90 | 82 | 26 | 22 | 17 | 11 |
| A 8397 | ♂ | Carnarvon | 11.VIII. 1959 | 82 | 74 | 23 | 15 $\frac{1}{4}$ | 10 | 10 |
| A 1215 | ♂ | Carnarvon | 21.IX. 1916 | 82 | 76 | ... | 18 $\frac{1}{4}$ | 14 $\frac{3}{4}$ | 9 $\frac{1}{4}$ |
| <i>virescens</i> | | | | | | | | | |
| A 8393 | ♂ | North-West Cape | 29.VII. 1959 | 94 | 82 | 25 | 22 | 15 $\frac{1}{4}$ | 10 |
| A 8395 | ♂ | North-West Cape | 30.VII. 1959 | 95 | 82 | 25 $\frac{1}{2}$ | 21 | 17 | 11 |
| A 8394 | ♂ | North-West Cape | 7.VIII. 1959 | 96 | 83 $\frac{1}{2}$ | 25 | 20 | 15 | 10 |
| A 8392 | ♂ | Bernier Island | 20.VII. 1959 | 97 | 82 | 27 | 22 | 17 $\frac{1}{2}$ | 11 $\frac{1}{2}$ |
| A 8388 | ♂ | Dorre Island | 18.VII. 1959 | 96 | 84 | 26 | 23 | 18 | 11 |
| A 8389 | ♂ | Dorre Island | 19.VII. 1959 | 98 | 86 | 24 | 22 $\frac{3}{4}$ | 17 | 11 |
| 10539 | ♂ | Dorre Island | 10.VIII. 1910 | 89 | 84 | 26 | 23 | 17 | 10 $\frac{1}{2}$ |
| A 8391 | ♂ | Dorre Island | 15.VII. 1959 | 90 | 80 | 24 $\frac{1}{4}$ | 21 | 16 | 11 |
| A 8390 | ♂ | Dorre Island | 19.VII. 1959 | 91 | 82 | 24 $\frac{3}{4}$ | 22 | 17 | 11 $\frac{1}{2}$ |
| A 1216 | ♂ | Dirk Hartog Island | 14.X. 1916 | 97 | 87 | 26 | 24 | 18 | 11 $\frac{1}{2}$ |
| A 2459 | ♂ | Dirk Hartog Island | 23.IV. 1922 | 99 | 87 | 26 | 23 | 17 | 10 $\frac{3}{4}$ |
| A 1217 | ♂ | Dirk Hartog Island | 12.X. 1916 | ... | 79 | 24 $\frac{1}{2}$ | 22 $\frac{1}{4}$ | 16 $\frac{3}{4}$ | 10 |
| A 2458 | ♂ | Peron Peninsula | 17.IV. 1922 | 97 | 85 | 26 $\frac{1}{2}$ | 22 $\frac{1}{2}$ | 16 | 11 |
| A 7210 | ♂ | Payne's Find | 22.V. 1953 | 89 | 82 | 23 $\frac{1}{2}$ | 19 $\frac{3}{4}$ | 14 $\frac{1}{4}$ | 10 |
| 6912‡ | ♂ | Ebano | Oct., 1904 | 91 | 85 | 23 $\frac{1}{4}$ | 18 $\frac{3}{4}$ | 14 | 9 |
| 6915 | ♂ | Ebano | Oct., 1904 | 93 | 85 $\frac{1}{2}$ | 24 $\frac{3}{4}$ | 19 | 13 $\frac{1}{2}$ | 9 $\frac{1}{2}$ |
| A 7100 | ♂ | Dandaragan | 17.IV. 1953 | 86 | 78 | 23 $\frac{3}{4}$ | 18 $\frac{3}{4}$ | 15 $\frac{1}{4}$ | 10 |
| A 7101 | ♂ | Morawa | 15.IV. 1953 | 92 $\frac{1}{2}$ | 80 | 25 $\frac{1}{4}$ | 20 | 14 $\frac{3}{4}$ | 9 $\frac{3}{4}$ |
| A 7102 | ♂ | Morawa | 15.IV. 1953 | 86 | 78 $\frac{1}{2}$ | 21 $\frac{1}{2}$ | 18 | 14 | 9 $\frac{1}{2}$ |
| A 7700 | ♂ | Wyalkatchem | 7.XI. 1955 | 93 | 82 | 24 $\frac{3}{4}$ | 19 $\frac{1}{2}$ | 15 | 10 $\frac{3}{4}$ |
| 6301 | ♂ | Wongan Hills | 7.X. 1902 | 89 | 81 | 24 $\frac{1}{4}$ | 22 | 15 | 9 $\frac{1}{4}$ |
| 4456 | ♂ | North Beach | 14.XI. 1901 | 91 | 85 | 25 | 22 $\frac{3}{4}$ | 16 | 11 |
| 4478 | ♂ | South Beach | 26.XI. 1901 | 90 | 80 | 25 | ... | 13 | 7 $\frac{3}{4}$ |
| 8039 | ♂ | Boyadine | 29.XII. 1905 | 97 | 88 | 24 $\frac{1}{4}$ | ... | ... | ... |
| 8421 | ♂ | Emu Hill | 6.VII. 1906 | 95 | 81 $\frac{1}{2}$ | 23 $\frac{1}{4}$ | 20 | 16 | 10 $\frac{1}{4}$ |
| 2242 | ♂ | Gracefield | 16.V. 1900 | 98 | 88 | 25 | 21 | 17 | 10 $\frac{1}{2}$ |
| 1074 | ♂ | Gracefield | June, 1899 | 98 | 86 | 25 | 20 | 15 $\frac{1}{2}$ | 11 |
| 5311 | ♂ | Stirling Ranges | Sept., 1902 | 94 | 80 | 24 $\frac{1}{2}$ | 20 $\frac{1}{4}$ | 16 | 11 |

* Type of *lewisi*.† Type of *lipferti*.‡ Type of *glauerti*.

TABLE LX—continued

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|-----------------------------|--------|------------------------|--------------|-------------------|------------------|------------------|------------------|------------------|------------------|
| <i>virescens</i> —continued | | | | | | | | | |
| 5331 | | Harvey River | 1.X. 1902 | 101 | 86 | 25 $\frac{3}{4}$ | .... | .... | .... |
| 3817 | ♂ | Harvey River | 15.V. 1902 | 87 | 81 | 24 $\frac{1}{4}$ | 21 $\frac{1}{2}$ | 16 | 11 |
| 6653 | ♂ | Harvey River | 26.I. 1904 | 99 | 89 | 25 $\frac{1}{4}$ | 23 | 17 | 12 |
| 5140 | ♂ | Mandurah | 13.IX. 1902 | 95 | 81 | 25 $\frac{1}{4}$ | 21 $\frac{1}{2}$ | 16 $\frac{3}{4}$ | 11 |
| 5178 | ♂ | Mandurah | 13.IX. 1902 | 88 $\frac{1}{2}$ | 76 | 25 | 23 | 18 $\frac{1}{4}$ | 12 |
| 5177 | ♂ | Mandurah | 13.IX. 1902 | 88 | 79 | 23 $\frac{1}{2}$ | 20 $\frac{3}{4}$ | 15 | 10 |
| 4359 | ♂ | Ellensbrook | Oct., 1901 | 87 | 76 | 24 | 20 | 15 | 10 $\frac{1}{4}$ |
| A 1213 | ♂ | Vasse River | 12.II. 1916 | 97 | 89 | 24 $\frac{1}{2}$ | 21 | 16 | 10 |
| 10127 | ♂ | Rottneet Island | 15.VII. 1909 | 98 | 89 $\frac{1}{2}$ | 26 | 23 | 16 $\frac{1}{2}$ | 11 $\frac{1}{2}$ |
| 10128 | ♂ | Rottneet Island | 24.VII. 1909 | 101 | 90 | 27 | 21 $\frac{1}{2}$ | 16 $\frac{3}{4}$ | 11 |
| 10130 | ♂ | Rottneet Island | 24.VII. 1909 | 100 $\frac{1}{2}$ | 91 | 26 | 22 | 15 $\frac{1}{2}$ | 11 $\frac{1}{4}$ |
| 5759 | ♂ | Rottneet Island | 13.VII. 1903 | 99 | 91 | 26 $\frac{1}{2}$ | 21 $\frac{3}{4}$ | 16 | 11 $\frac{1}{4}$ |
| 6499 | ♂ juv. | Rottneet Island | 14.XI. 1903 | 92 $\frac{1}{2}$ | 85 | 26 | 21 $\frac{3}{4}$ | 15 $\frac{1}{4}$ | 10 $\frac{1}{2}$ |
| 4710 | ♂ | Rottneet Island | 10.II. 1902 | 91 | 81 | 27 | 20 | 15 $\frac{1}{4}$ | 11 |
| 5762 | ♂ | Rottneet Island | 13.VII. 1903 | 99 | 91 | 26 $\frac{1}{4}$ | .... | .... | .... |
| 6498 | ♂ | Rottneet Island | 7.XI. 1903 | 100 | 89 | 25 $\frac{3}{4}$ | 20 $\frac{1}{2}$ | 15 | 10 $\frac{1}{2}$ |
| 5763 | ♂ | Rottneet Island | 13.VII. 1903 | 98 | 86 | 27 | 22 | 16 | 11 $\frac{1}{2}$ |
| 5404 | ♂ juv. | Rottneet Island | 21.IV. 1903 | 91 $\frac{1}{2}$ | 79 | 25 $\frac{1}{2}$ | 20 | 14 $\frac{3}{4}$ | 10 $\frac{1}{2}$ |
| 10129 | ♂ | Rottneet Island | 15.I. 1909 | 98 | 90 | 26 $\frac{1}{4}$ | 20 $\frac{1}{4}$ | 16 | 10 $\frac{1}{4}$ |
| 4711 | .... | Rottneet Island | 10.II. 1902 | 96 | 89 | 26 $\frac{1}{2}$ | 20 $\frac{1}{2}$ | 15 $\frac{1}{4}$ | 10 $\frac{3}{4}$ |
| 6380 | .... | Rottneet Island | Nov., 1903 | 99 | 88 | 27 | 22 $\frac{1}{4}$ | 16 $\frac{1}{4}$ | 11 $\frac{3}{4}$ |
| 6378 | .... | Rottneet Island | Nov., 1903 | 95 | 84 | 25 | 18 $\frac{1}{2}$ | 15 | 11 |
| 4712 | .... | Rottneet Island | 10.II. 1903 | 89 | 85 | 24 | 18 $\frac{1}{2}$ | 15 | 10 $\frac{3}{4}$ |
| 5767 | .... | Rottneet Island | 13.VII. 1903 | 92 | 87 | 24 $\frac{1}{2}$ | 20 | 14 $\frac{3}{4}$ | 10 |
| A 6514 | ♂ | Garden Island | 17.XI. 1948 | 89 | 77 $\frac{1}{2}$ | 24 $\frac{1}{2}$ | 19 $\frac{1}{4}$ | 14 | 9 $\frac{1}{4}$ |
| A 6515 | ♂ | Garden Island | 17.XI. 1948 | 86 | 76 $\frac{1}{2}$ | 21 $\frac{1}{2}$ | 18 $\frac{1}{2}$ | 14 | 9 |
| A 6516 | ♂ | Garden Island | 17.XI. 1948 | 92 | 82 | 23 $\frac{1}{2}$ | 21 $\frac{1}{4}$ | 16 $\frac{1}{2}$ | 11 |
| A 6517 | ♂ | Garden Island | 17.XI. 1948 | 85 | 79 $\frac{1}{2}$ | 24 | 21 $\frac{1}{4}$ | 16 | 10 $\frac{1}{2}$ |
| 8330 | + | South Twin Peak Island | 12.V. 1906 | 92 | 78 | 24 | 17 $\frac{1}{2}$ | 13 $\frac{1}{4}$ | 8 $\frac{3}{4}$ |
| 8332 | . | South Twin Peak Island | 12.V. 1906 | 93 | 81 | 25 $\frac{1}{4}$ | 20 | 14 $\frac{1}{2}$ | 10 |

Type of *insularis*.

TABLE LXI

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|--------|-------------|--------|------------------|------------------|------------------|------------------|------------------|-----------------|
| A 8314 | ♂ | Mt. Herbert | 24.VII | 71 | .... | 19 | 16 | 11 $\frac{1}{4}$ | 7 $\frac{3}{4}$ |
| A 8321 | ♂ | Tambrey | 28.VII | 79 $\frac{1}{2}$ | 62 $\frac{1}{2}$ | 21 | 18 | 13 | 8 $\frac{1}{4}$ |
| A 8316 | ♂ | Tambrey | 31.VII | 80 | 65 | 20 $\frac{1}{2}$ | 17 | 12 $\frac{1}{2}$ | 8 $\frac{3}{4}$ |
| A 8313 | + | Millstream | 26.VII | 70 $\frac{1}{2}$ | 55 | 20 | 14 $\frac{1}{2}$ | 11 $\frac{1}{2}$ | 7 $\frac{1}{4}$ |
| A 8315 | + | Tambrey | 28.VII | 68 | 53 | 19 $\frac{3}{4}$ | 15 $\frac{1}{2}$ | 12 | 7 $\frac{1}{2}$ |
| A 8319 | + | Tambrey | 28.VII | 73 | 57 | 20 | 15 $\frac{1}{2}$ | 11 $\frac{3}{4}$ | 8 |
| A 8320 | + | Tambrey | 28.VII | 75 | 58 | 19 $\frac{1}{4}$ | 15 $\frac{3}{4}$ | 12 | 8 |
| A 8311 | + | Tambrey | 29.VII | 81 | 66 $\frac{1}{2}$ | .. | 16 | 12 | 8 $\frac{1}{4}$ |
| A 8322 | + | Tambrey | 30.VII | 79 | 62 $\frac{1}{2}$ | 22 | 17 $\frac{1}{4}$ | 13 $\frac{1}{4}$ | 8 $\frac{1}{4}$ |
| A 8317 | + | Tambrey | 31.VII | 80 | 65 | 20 $\frac{1}{2}$ | 17 | 12 $\frac{1}{2}$ | 8 $\frac{3}{4}$ |
| A 8312 | ♂ juv. | Tambrey | 29.VII | .... | .... | .... | .... | .... | .... |
| A 8318 | ♂ juv. | Tambrey | 31.VII | .... | .... | .... | .... | .... | .... |

TABLE LXII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|----------------------|--------|------|------------------|------------------|------------------|------------------|-----------------|
| A 8168 | ♂ | Goola Lake, Roy Hill | 12.VII | 73 | 62 $\frac{1}{2}$ | 21 | 16 $\frac{1}{2}$ | 12 | 7 $\frac{3}{4}$ |
| A 8172 | ♂ | Millstream | 21.VII | 81 | 68 | 21 | 17 | 13 $\frac{1}{2}$ | 9 $\frac{1}{4}$ |
| A 8169 | . | Millstream | 19.VII | 74 | 64 | 21 | 15 $\frac{1}{4}$ | 12 $\frac{1}{4}$ | 7 $\frac{3}{4}$ |
| A 8170 | . | Millstream | 19.VII | 76 | 68 | 19 | 16 $\frac{1}{2}$ | 12 $\frac{1}{4}$ | 7 $\frac{3}{4}$ |
| A 8171 | . | Millstream | 19.VII | 83 | 71 | 21 $\frac{1}{2}$ | 17 | 13 $\frac{1}{2}$ | 9 $\frac{1}{4}$ |

TABLE LXIII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|------------------|--------|------|------|------------------|------------------|------------------|------------------|
| A 8239 | ♂ | Mt. Herbert | 24.VII | 133 | 111 | 31 | 28 | 20 $\frac{1}{4}$ | 13 $\frac{3}{4}$ |
| A 8241 | ♂ | Tambrey | 27.VII | 136 | 111 | 30 | 26 | 20 | 13 $\frac{1}{4}$ |
| A 8240 | ♂ | Tambrey | 3.VIII | 136 | 111 | 32 | 25 $\frac{1}{2}$ | 19 $\frac{1}{4}$ | 13 $\frac{1}{2}$ |
| A 8242 | ♂ | Tambrey | 30.VII | 127 | 112 | 30 $\frac{1}{2}$ | 28 | 20 | 14 |

TABLE LXIV

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. |
|--------|--------|-----------------|--------|------------------|------------------|------------------|------------------|
| A 8181 | ♂ imm. | Millstream | 26.VII | 59 | 35 | 14 | 11 |
| A 8186 | ♂ | Tambrey | 29.VII | 58 $\frac{1}{2}$ | 37 | 13 $\frac{3}{4}$ | 12 $\frac{1}{2}$ |
| A 8183 | ♂ | Tambrey | 1.VIII | 61 | 37 $\frac{1}{2}$ | 15 | 12 $\frac{1}{4}$ |
| A 8184 | ♂ | Tambrey | 1.VIII | 59 $\frac{1}{2}$ | 35 | 15 | 12 |
| A 8185 | ♂ | Tambrey | 1.VIII | 61 | 37 | 15 | 10 $\frac{3}{4}$ |
| A 8187 | ♂ | Tambrey | 4.VIII | 58 | 36 | 14 | 12 |
| A 8182 | ♂ | Millstream | 26.VII | 59 | 32 | 14 $\frac{1}{4}$ | 9 $\frac{1}{4}$ |

TABLE LXV

| No. | Sex | Location | Date | Wing | Tail | Tars. | Exp. cul. |
|--------|-----|-----------------|--------|------------------|------------------|------------------|------------------|
| A 8195 | ♂ | Millstream | 26.VII | 56 | 33 | 13 | 10 $\frac{1}{4}$ |
| A 8198 | ♂ | Millstream | 28.VII | 57 $\frac{1}{2}$ | 34 | 14 | 10 $\frac{1}{2}$ |
| A 8196 | ♂ | Tambrey | 31.VII | 58 | 33 | 14 $\frac{1}{4}$ | 10 |
| A 8199 | ♂ | Millstream | 28.VII | 53 | 30 | 14 | 8 |
| A 8200 | ♂ | Millstream | 28.VII | 57 | 33 | 14 $\frac{1}{2}$ | 8 |
| A 8197 | ♂ | Tambrey | 31.VII | 53 $\frac{1}{2}$ | 30 $\frac{1}{2}$ | 13 $\frac{1}{4}$ | 9 |

TABLE LXVI

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|-----------------|--------|------|------|-------|------------------|------------------|------------------|
| A 8275 | ♂ | Millstream | 19.VII | 164 | 110 | 39 | 25 $\frac{1}{2}$ | 20 $\frac{1}{4}$ | 15 $\frac{1}{2}$ |
| A 8274 | ♂ | Tambrey | 1.VIII | 184 | 124 | 42 | 28 | 20 $\frac{1}{2}$ | 16 |

TABLE LXVII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|-----------------|--------|------|------|------------------|------------------|------------------|------------------|
| A 8140 | ♂ | Millstream | 25.VII | 128 | 57 | 16 | 19 $\frac{1}{4}$ | 17 | 12 $\frac{3}{4}$ |
| A 8139 | ♂ | Millstream | 19.VII | 132 | 60 | 17 $\frac{1}{2}$ | 20 $\frac{1}{2}$ | 16 $\frac{1}{4}$ | 13 $\frac{1}{4}$ |
| A 8141 | ♂ ? | Millstream | 25.VII | 131 | 58 | 17 $\frac{1}{2}$ | 22 $\frac{1}{2}$ | 18 $\frac{1}{2}$ | 13 |

TABLE LXVIII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|--------------|--------|------|------|-------|------------------|------------------|------------------|
| A 8153 | ♂ | Tambrey | 1.VIII | 124 | 74 | 19 | 23 $\frac{1}{2}$ | 19 $\frac{1}{4}$ | 14 $\frac{1}{4}$ |

TABLE LXIX

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|-----------------|--------|------|------|-------|--------------|--------------|----------------|
| A 8154 | ♀ | Millstream | 18.VII | 112 | 68 | 21 | 21 | 17½ | 13 |
| A 8155 | ♀ | Millstream | 28.VII | 113 | 66 | 20½ | 18 | 16½ | 11½ |
| A 8156 | ♀ | Millstream | 28.VII | 116 | 67 | 21 | 19 | 16½ | 12 |
| A 8157 | ♀ | Millstream | 25.VII | 121 | 70 | 20½ | 20 | 17 | 13 |

TABLE LXX

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|-----------------|--------|------|------|-------|--------------|--------------|----------------|
| A 8148 | ♂ | Tambrey | 29.VII | 107 | 59½ | 14¾ | 13½ | 11 | 8¼ |
| A 8149 | ♂ | Tambrey | 29.VII | 109 | 60 | 13¾ | 14¼ | 11 | 8 |
| A 8150 | ♂ | Tambrey | 29.VII | 109 | 60 | 13¾ | 14 | 11½ | 8 |
| A 8151 | ♂ | Tambrey | 29.VII | 102 | 57 | 14 | 14 | 12½ | 8¼ |
| A 8152 | ♂ | Tambrey | 29.VII | 102½ | 62 | 14½ | 13 | 11¼ | 8 |
| A 8145 | ♂ | Millstream | 20.VII | 104 | 60 | 12¾ | 15¾ | 11½ | 8¼ |
| A 8146 | ♂ | Millstream | 21.VII | 110 | 60 | 14 | 15½ | 13 | 8½ |
| A 8147 | ♂ | Millstream | 22.VII | 109 | 62 | | 14¾ | 12 | 8¼ |

TABLE LXXI

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|------------------|--------|------|------|-------|--------------|--------------|----------------|
| A 8134 | ♂ | Tambrey | 28.VII | 179 | 131 | 36 | .... | 51 | 38 |
| A 8133 | + | Mt. Herbert | 24.VII | 178 | 135 | 36½ | .... | 46½ | 34 |

TABLE LXXII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|--------------|--------|------|------|-------|--------------|--------------|----------------|
| A 8000 | ♂ | Tambrey | 4.VIII | 252 | 134 | 56 | .. | 63 | 46 |
| A 7999 | ♂ | Tambrey | 2.VIII | 235 | 123 | 48½ | .... | 56½ | 40½ |

TABLE LXXIII

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|------|-----------------|--------|------|------|-------|--------------|--------------|----------------|
| A 8341 | ♂ | Marillana | 12.VII | 144 | 90 | 39 | 29½ | 24½ | 17 |
| A 8342 | | Millstream | 26.VII | 150 | 89 | 39 | 29 | 22 | 15½ |

TABLE LXXIV

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|-----------------|--------|------|------|-------|--------------|--------------|----------------|
| A 7977 | ♂ | Millstream | 22.VII | 317 | 172 | 55 | 50 | .. | 32 |

TABLE LXXV

| No. | Sex | Location | Date | Wing | Tail | Tars. | Ent. cul. | Exp. cul. | Cul. nostr. |
|--------|-----|-----------------|--------|------|------|-------|--------------|--------------|----------------|
| A 7980 | ♂ | Tambrey | 2.VIII | 360 | 189 | 58 | 60 | .... | 38½ |
| A 7979 | | Millstream | 2.VIII | 356 | 189 | 60½ | 61¾ | .... | 41½ |
| A 7978 | | Millstream | 28.VII | 335 | 180 | 59½ | 58 | .... | 40½ |

